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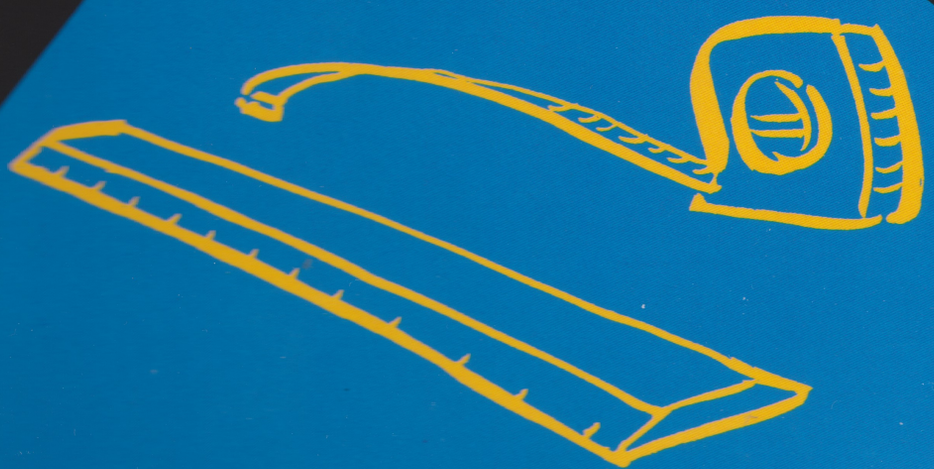
K507/1 SB

Breakthrough to Mathematics, Science and Technology

THINKING ABOUT MEASUREMENT

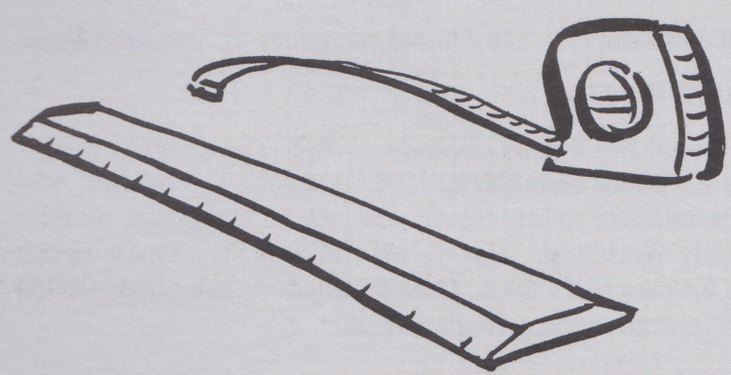


The Open University

Breakthrough to Mathematics, Science and Technology

MODULE STUDY BOOK
THINKING ABOUT MEASUREMENT

Prepared for the Course Team by Barbara Allen, Heather Cooke, Hilary Evens and Hilary Holmes



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PROLOGUE BEFORE YOU START

This study module has been written to encourage *active* learning. This means that you are expected to do more than just read the text. From time to time you will meet activities to be carried out.

The activities are of several kinds:

- some will pose questions
- some will set tasks, such as taking notes
- some will simply encourage you to think about what and how you are learning.

These activities are a vital part of your studies, so allow yourself enough time to complete them.

At the end of the module, you will find a skills audit (Table 19 in Activity 65 on page 93) which will help you to appreciate just how much you have gained from your studies. It will make even more sense if you contrast it with the state of your skills before you begin, so turn to Activity 65 now and complete the columns for skills levels on your own assessment.

The total time needed to study this module carefully (including all the activities, the associated reading and the audio-cassette) will depend upon your individual circumstances and needs. Somewhere between 15 and 30 hours is our best estimate. If you find you are taking a great deal longer, it might be a good idea to seek advice from a tutor or a friend more experienced in studying.

Apart from reading the Study Book itself, you will need a copy of *The Sciences Good Study Guide* (the SGSG). You don't have to have read this book in any detail before you begin the module, but it will help if you are familiar with the overall plan. If you are able to spend more time reading the SGSG beforehand, so much the better. Whatever your approach, you should find that working through the particular parts of the SGSG linked with this module in some detail will give you an opportunity to identify and practise important study skills. We hope that you'll eventually feel encouraged to study other modules, which will give you experience of a wider range of study skills.

This Study Book will tell you when to study the relevant parts of the SGSG, and you will also find an SGSG icon in the margin, like the one here.

You may find you need to spend extra time working through the Maths Help section of the SGSG (pages 301 to 395), because numerical work requires practice. It is up to you to spend as much time as you feel you need.

CHAPTER 1 GETTING STARTED

Jack and Jill went up the hill
To fetch a pail of water;
Jack fell down and broke his crown,
And Jill came tumbling after.

A nursery rhyme about seventeenth-century measures

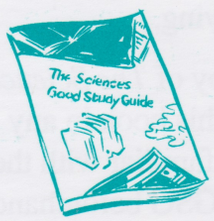
1.1 Introduction to the module

This module introduces you to some of the uses and limitations of measuring size, as well as giving you a taste of using distance-learning materials for higher education.

It offers a number of activities to help you learn and practise your study skills, while learning about measurement as used in the sciences. Many of the activities are aimed at helping you become an effective learner, so try to work through them all.

Activity 1 Making a start

Study skills



pages 12 to 14

If you have not done so already, now is the time to get yourself organized, ready to study. On the Bookmark that you received with this module there are various suggestions, including setting up a (loose-leaf) Study Folder that includes a Study Diary, a section for notes and a personal dictionary.

Make sure you have read Chapter 1 of the SGSG, or at least Section 3.3 'Practical arrangements', which begins on page 12.

Over the years, you are likely to have had a great deal of experience of measures and measuring. This module builds upon that experience, in order to give you a greater understanding and insight. The module gradually introduces the following aspects of measurement:

- reasons for measuring
- what any particular measurement includes (that is, the boundaries)
- what the units of measurement are and how to convert from one to another
- using measuring tools to make 'good' measurements.

This chapter should lead you to think about measuring in general and to become more aware of the measurements you already make and use.

The next two chapters consider the everyday activities of cooking and travelling by road, but from a more technical or scientific angle than is probably familiar to you. Later chapters take you more into the worlds of technology and science, again building on familiar experiences.

Specific topics were chosen to make your studies more interesting, but they are not in themselves particularly significant. By the end of the module you will be expected to know and understand a great deal more about measurement, but you are not expected to retain a lot of information on the topics themselves.

The chapters vary in length, pace and content. You need to bear this in mind when planning your studies. The variations were built in, to allow you to find out about how you learn. You can then develop strategies for keeping up your morale and overcoming any difficulties you might meet. Every learner is different and there is no 'best way' to learn. There are, however, strategies that have been found to help. This module and the supporting SGSG will give you the opportunity to use and practise some of these strategies, so that you can decide for yourself what works best for you.

Activity 2 Getting an overview

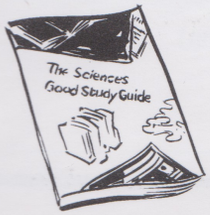
Study skills

Flip through the whole Study Book to get a feel for what is in it, how it is organized and how familiar you are with the topics. Glance at the general layout of the chapters. You can get an idea of the content by skimming over the headings and subheadings, without reading any detail. At the end of each chapter is a summary box, headed 'Learning Outcomes'. Observe how these boxes give you an overview of what is in each chapter and think about how they might help you to plan your studies.

This is what one student wrote in response to Activity 2.

The chapters all have lots of text and diagrams but are broken up into chunks by having things to do (activities) all the way through.

The end 'Learning Outcomes' boxes are a summary of what each chapter is about – it might be useful to read these before as well as after doing a chapter.



pages 36 to 37

Looking through what you have to study will help you plan ahead. What you're doing is quickly skimming through many pages of text, a skill you can read more about in the SGSG.

Now that you have some sort of overview of the module, it is time to start work. Do remember to try to enjoy the process of learning!

1.2 Measuring in general

Human beings seem to share a desire to make measurements of everything around them, either by counting or by comparison with something else. Even very young children are aware of size. For example, they observe and discuss which of their friends is bigger than they are, or who has more chocolate.

Increasingly, numerical measures are being used in the market place. For example, warmth factors for duvets are now quoted in British Standard Tog Ratings, while sun creams are given a numerical protection factor. Measures of all kinds are used a great deal in everyday life: you have no doubt used many different ones yourself, for all kinds of purposes.

Activity 3 Familiar measures

Try to recall those things you have come across in the last day or so that are quantities or measures of some kind. Write down a list of at least ten kinds of measure, and note in what connection you met them.

Only you can know what you have met recently but you might have included some of the measures shown in Table 1.

Table 1 Various measures and their uses

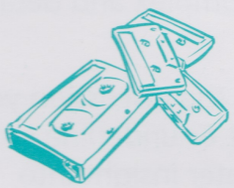
Measures	Used for ...
large, medium, small	eggs, soft drinks
numerical sizes	shoes, clothing
hours and minutes	watch, video or microwave timer; appointments
stones and pounds	bathroom scales
kilograms	bathroom scales, bag of potatoes, sugar
miles and yards	road signs
miles per hour	speed limits
degrees	weather forecast, thermometer, oven temperature control
kilohertz	radio frequencies (for example, the jingle '88–91 FM, Radio Two')
pints	milk bottle or beer glass
litres and centilitres	petrol, soups, milk or wine
millilitres	medicines (for example, a 5 ml spoon)
calories (sometimes Calories or kilocalories)	on food packets and diet sheets

There are several different kinds of measure in this list; for example:

- direct comparisons, such as offers of 'large' or 'small' pineapples when the customer has a choice; otherwise it is just 'pineapples'
- imperial (the British system), such as pounds, pints or yards
- metric, such as litres or kilograms.

The UK is gradually going over to the metric system for common use, while in the world of science there is widespread international agreement on using the metric-based *Système International* (SI), which is covered in more detail in later chapters.

Activity 4 Jack and Jill



Think about various uses of the measures you have met. Then listen to the first section of the audio-cassette. A short, dramatic element is followed by two mathematicians (a historian and an educator) talking about measurements.

As well as listening to what is said, notice *how* you listen, and think about what you are going to do with the information presented.

Activity 5 Using audio-cassettes

Study skills

page 174

Read the brief paragraph entitled 'Audio-cassettes' on page 174 of the SGSG. It contains ideas on how to make the best use of audio.

Did you adopt a particular approach when listening to the Jack and Jill audio-cassette section? Did you stop and start the audio-cassette? Did you have paper and pencil to hand?

You need to think about how you can make the best use of any particular audio. Some people find it difficult to absorb information presented in this way, while others find it helps them to form their own mental imagery.

Learning at a distance is not like being in a real-time lecture, where there is only one chance to get all the information.

You may feel that you do not yet know enough to decide about the importance of a particular piece of audio. You may not even have much time available at the moment. That is fine at this stage. The advantage of a distance-learning module is that you always have the audio-cassette, so you can listen again later.

You have the materials: you can decide how and when to use them.

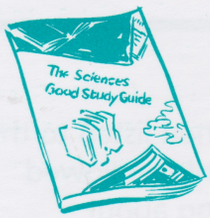
If you found this audio material of only general background interest or not immediately vital, it might be worth making just a few notes on the content and keeping them for reference.

Suggestions on how to organize your notes into a Study Folder are on the Bookmark.

If you found it especially interesting, then listen again, jotting down particularly important points or questions as you listen. You can then write up more detailed notes from these jottings, using underlining or highlighter pens to emphasize the most significant points. Again, keep these notes, so that you can find and refer to them when doing a later activity, writing an assignment, or revising.

Activity 6 Making audio notes

Study skills



page 46

How useful did you find the notes you made? Read through the box on page 46 in the SGSG, which deals with highlighting and underlining.

An alternative way to summarize ideas is by drawing 'spray diagrams'. Figure 2.5 (on page 49 in the SGSG) shows how this sort of diagram is used, although the example included is much more complex and detailed than any you require now.

What were the most interesting ideas to emerge from the discussion you just heard? Look at the notes you made, and highlight or underline two or three points that were new to you or gave you greater insight into measurement.

Your notes will be personal to you, but here is an example of what one student highlighted when faced with the same task.

> *The counting or measurement system adopted depends on what people want to do with it and what people will accept.*
>
> *Metric measures were designed to be rational and the named units are in tens or tenths or powers of ten or a tenth.*
>
> *Imperial measures were based on the sorts of things people commonly used or on human body relationships.*
>
> *Time is still measured in units of 60, the same base as used by the Babylonians.*

Activity 7 Reading about measuring

Study skills

pages 24 to 55

Chapter 2 of the SGSG is concerned with reading and making notes. You may be unable to read all of it now, but do scan through the lists of Key Points. You will need to find your own way of *engaging* with the knowledge in the text (the term used in the Key Points box on page 55). This simply means getting to grips with what you read.

The following extract was written by David Pimm, one of the people you have just listened to on the audio-cassette. Read it now and make brief notes.

> The central use of measuring is [...] comparison. Is this *bigger* than that, *longer* than that, *older* than that? We don't always need numbers if we wish to compare things. In order to achieve a direct comparison, the two objects (situations) need to be brought 'next to' each other in some sense, so they touch: two children can stand back to back to decide who is the taller, two small objects can be put in opposite pans of a balance and directly visually compared with respect to weight, and so on.
>
> But often objects being compared cannot be brought next to each other in this way: they may be too small, or too far away from each other, or be immovable for some reason. For example, you may want to check whether a heavy piece of downstairs furniture will fit into an alcove in an upstairs bedroom. A third object can be used as a measure – one that can be moved from one to the other, laid against one and then laid against the other: a portable common comparison.
>
> Measuring can be used to short-circuit the problems of comparing directly. By measuring numerically, we assign a number to each object and then the numbers can *always* be 'brought together' (mentally) to be compared with one another. Once you have worked out which is the larger *number*, that becomes the basis for deciding which *object* is the larger/older/heavier ... The numbers become the counterpart of the material-world object, process or situation. And an important justification for using numbers as measures is that any two numbers can be ordered; that is, in principle we can always decide which one is the bigger, and which the smaller.
>
> Pimm (1995)

The significant points made in this extract are that:

- the central purpose of measurement is comparison of size
- by using numerical units, measurements can be put in order of size and the size of objects compared without having to bring the objects together.

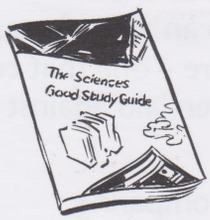
Check your notes to see that they include the above points.

1.3 The sciences and measurement

Mathematics, the sciences and technology (referred to in the SGSG as 'the MST subjects') are all concerned, to varying extents, with the various properties of objects or organisms, energy, populations, materials and spaces, and the relationships between them. The size, amount or quantity of something are significant properties or features of it, and need to be used or taken into account by the individuals working in particular sciences.

However, the different sciences, sometimes even the different disciplines making up one area of science, all make and use measurement in different ways. Although measurement is mathematical, in the sense that numbers are involved, mathematicians and theoretical scientists are rarely concerned with the actual process of measuring. On the other hand, many observational scientists, in such diverse fields as astronomy, geochemistry, botany, nuclear physics and so on, need to make measurements as part of their daily work. Technologists also need to make and use measurements as part of their studies of the properties and behaviour of materials, structures and machines.

For most scientists, measurements are the result of careful observations and experiments. You can learn more about these important scientific skills in Chapter 8 of the SGSG.



pages 199 to 227

Make a note in your Study Diary to read all of this chapter at a convenient time. Right now, it would be useful to read the section starting on page 199 of the SGSG entitled 'How can you spot a scientist?', which deals with some of the differences between the disciplines of mathematics, science and technology.

The rest of this module is concerned with the process of measuring, and how the results of that process should be used. It is therefore geared more to the practical sciences than to the theoretical. However, measurements are very much part of everyday life, so whatever you may study in the future, it is valuable to understand more about the process of measurement in general.

Activity 8 Reflecting

Study skills

pages 47 to 53

Reflecting on what you have learned is an important skill. The process is helped by making summary notes, as discussed in Chapter 2 of the SGSG. You will often need to make notes, either in sentences or as a spray diagram. Make a note in your Study Diary to read all of Chapter 2 at some convenient point.

Think about what you knew about measurement as a process before starting the module, and what you now know. Make some summary notes or draw a spray diagram to summarize what you have learned. While you may have learned no new facts, you may find you are thinking about measurement in a new way. You may be noticing more about the measurements you use in everyday life and the purposes for which you use them.

You may feel that you are not sure what you should be writing at this stage. However, the act of just *trying* to summarize is part of the learning process. It helps you to concentrate on the work you have been doing, to order your knowledge and ideas. It also provides a record of what you have studied. You may need to look back at your notes when writing an

essay or preparing for an exam, or producing evidence of previous study. Using coloured highlighter pens is a useful way of making the key points stand out, either in the original next or in your own notes.

Learning Outcomes

You should now understand that:

- a variety of measurements and units are used in everyday life to describe quantities and to express relationships
- there is almost universal acceptance of a single, linked system of standard units (the SI system) for use in science and technology
- various strategies can be used to help you to learn from written texts and audio-cassettes.

You should now be more able to:

- use a variety of approaches and tactics when dealing with study materials, including:
  - skimming, to obtain an overview and to help you to plan your study
  - scanning, to identify important ideas
  - making brief notes, to help to clarify your own thoughts
  - summarizing, to reflect on and record what you have learned.

CHAPTER 2 IN THE KITCHEN

2.1 Introduction

Now that you have thought about some of the many activities you carry out that involve measuring, and considered why you measure quantities, it is time to look at one measuring activity in detail. Although following measures in a recipe is an everyday example, the main ideas of this chapter apply equally in many different scientific and technological situations.

This chapter begins by considering:

- what you need to measure
- which measuring tools you use
- how well you can measure
- how good these measurements need to be for different purposes.

There is a short section on the metric system, to help you feel more familiar with the main measuring system used by scientists. Finally, there is a brief look at some of the issues that arise when you use mathematics to solve practical problems. To help you learn effectively from this module, you will also be encouraged to do things, to make notes and to reflect constructively on your progress so far.

2.2 Mediaeval cookery

Mounchelet

Take veel other[wise] motoun and smyte it to gobettes. Seeth it in gode broth; cast therto erbes yhewe gode won, and a quantite of oynouns mynced, powdour fort and safroun, and alye it with ayren and verious: but let it not seeth after.

A mediaeval recipe quoted in Black (1992)

What should be measured, and how?

In mediaeval times, recipes were usually passed on by word of mouth. Cooks learned their craft through a mixture of 'hands-on' training and experimentation. Recipes tended to include only the kinds of ingredients used, and you were expected to fill in details such as the amounts and the methods yourself. To see what was involved, read through the recipe for mounchelet at the start of this section.

Probably the first thing you noticed about the recipe is that it is very difficult to understand because it is written in mediaeval language. Although you can

understand some of the words, such as 'take' and 'after', and guess at the meanings of others (onions for 'oynouns' perhaps), there are probably quite a few words whose meaning you have no idea of (for example, 'ayren' or 'alye').

Activity 9 Making sense

Study skills

pages 30 to 40

When you begin to study any new subject, including maths, science and technology, you will meet new ideas and vocabulary, which may at first be difficult to understand. Although scientific articles are obviously not written in mediaeval language, some can appear just as difficult to understand, so it is important to develop strategies for coping with them.

Use the index at the back of the SGSG to look, for example, under 'technical language' and 'getting stuck', for advice about coping with new ideas and terms. Pages 30 to 40 are good places to begin. Write down in your Study Folder a brief list of four or five tactics that you think will help you get over these hurdles.

page 92

Building up your own personal dictionary will help – perhaps an MST version of the dictionary shown on page 92 of the SGSG. Every time you meet a new word or phrase, or a word used in a different way, write it into your Study Folder. Once you understand what it means, record its meaning or use in your own words.

At the end of this chapter, you will be asked to review your Study Folder, including your Study Diary, to identify which ways of working are most effective for you. For example, you may decide that you work best in short, half-hour bursts, late at night when it is quiet, or in longer stretches at the weekend when you are fresh. By reflecting on your progress you can use your time as efficiently as possible.

Remember that Section 3 of Chapter 1 in the SGSG, 'How to get yourself organized', has more to say about how to manage your study.

Now have another look at the recipe for mounchelet. Here is a rough translation.

Lamb stew

Take some lamb (or mutton) and cut it into lumps. Boil the meat in some good stock. Throw in some herbs, good wine, a quantity of minced onions, spice powder and saffron. Thicken with eggs and lemon juice; but do not let it boil after that.

Activity 10 In a stew

In your Study Folder, write down some of the problems you might encounter if you were to try to make this stew. Include suggestions for overcoming these problems. Then compare your response with the comments below. Have you missed out any points or included any extra ones? Do you disagree with any? If so, why?

Although the recipe does allow you to produce some kind of mutton stew, it is unlikely to be exactly like the delicious stew made in the Middle Ages unless you know how much of each ingredient to use. How much meat do you need, and will two onions be enough or should you use four? It would also be helpful to know what size a 'lump' is, and how long to cook the meat. So, as a recipe it is really not very helpful: much more information is needed.

Here is a modern version.

The old English abbreviation lb actually stands for the Latin word for 'pound', *libra*.

Lamb stew – serves six

- 2 lb boneless stewing lamb or mutton cut into two-inch cubes
- 2 cups chicken stock
- 2 medium onions, peeled and finely chopped
- $\frac{1}{2}$–1 teaspoon each, fresh rosemary, thyme, and savory or marjoram leaves
- $\frac{1}{4}$ teaspoon each, ground ginger, cumin and coriander
- salt to taste
- 1 cup white wine
- 2 eggs
- 2 tablespoons lemon juice

Put the meat and stock into a stew pan and bring to the boil. Skim if needed, then add the onions, herbs, spices, salt and wine. Reduce the heat, cover the pan and cook gently until the meat cubes are cooked through and tender (1 to $1\frac{1}{2}$ hours). Beat the eggs with the lemon juice until blended, then take the pan off the heat and stir the egg mixture gradually into the stew to thicken it slightly. Do not re-boil.

Adapted from Black (1992)

This version certainly gives a much clearer picture of the quantities required. You probably possess a variety of cups, teaspoons and tablespoons you can use, and at least you know how many onions and eggs are needed. Of course, you still do not know precisely what size a 'cup' is or how big a 'medium' onion is or what size egg to use, but in practice this probably does not matter. Minor variations in a stew are unlikely to ruin it. So in this case, these informal and fairly approximate measurements are perfectly adequate for the purpose.

Activity 11 Chef's special

Think of two recipes of your own, preferably ones that you have already used. (If you have never done any cooking for yourself, then talk to someone who has. But even making a cup of coffee or heating something up in a microwave involves some measurement. Think about it. How do you get the coffee to taste just as you like it?)

- Which items did you measure?
- What was the quantity?
- What units of measurement did you use?
- How did you measure them?

Summarize the results in a table in your Study Folder. And then think about why you measured what you measured.

pages 150 to 153

If you are unfamiliar with the way information is displayed in tables, quickly look through Section 5.2 of the SGSG (starting on page 150). Note that all the tables consist of a number of columns with headings. What headings would be appropriate for your cookery examples?

Your table could be laid out something like Table 2.

Table 2 Cookery measurements

Item measured	Quantity	Units	Equipment used

Depending on your recipe, you probably had to measure one or more of the following quantities.

- Dry ingredients, measured in grams, kilograms, ounces (oz) or pounds (lb) using kitchen scales.
- Liquids, measured in millilitres, litres, fluid ounces or pints using a measuring jug.
- Time, measured in minutes and hours using a clock or oven timer.
- Temperature, measured in degrees Celsius (°C) or Fahrenheit (°F) or the 'gas mark' scale.
- Length, used to determine the size of a cake tin, and measured in centimetres or inches using a ruler or tape measure.

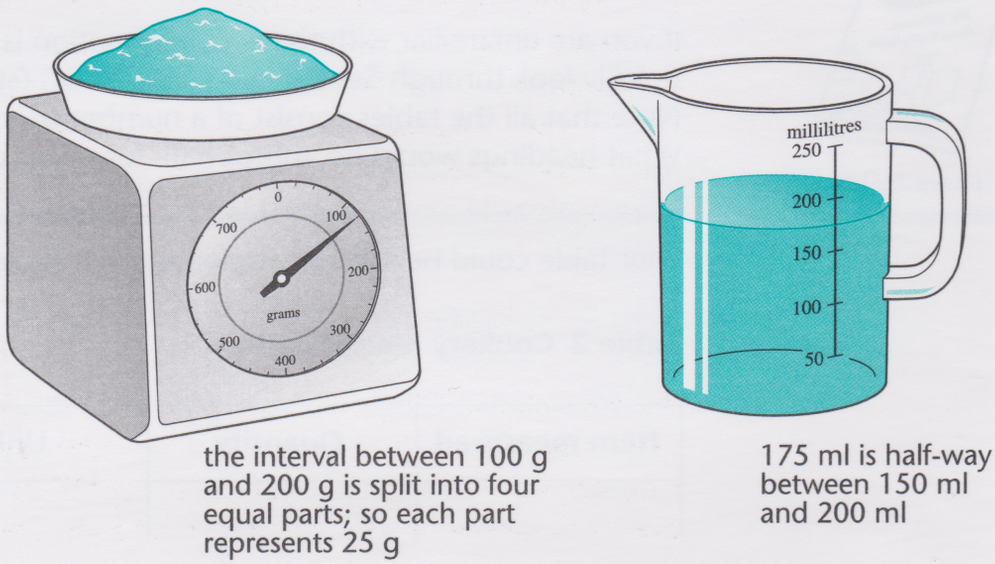
Remember your personal dictionary.

Pause for a moment. In the list above, are there any words or symbols you are not familiar with (for example, 'degrees Celsius (°C)' or 'Fahrenheit (°F)')? If so, then you could find out what they mean now, either by asking someone or by using a dictionary, or you could come back to them later.

Thinking about equipment and its use is very important for any measurement.

When making the measurements, the amount of care you took would depend on the equipment you were using, and how closely you wanted your product to resemble the item described in the recipe.

Some recipes allow you to vary the amounts of certain of the ingredients, according to taste, while others rely on very careful measurements to ensure that the desired consistency and flavour are achieved. For example, if you are making a pie with a biscuit crumb base, it is important that the proportions of biscuit, syrup, butter and sugar are correct. Otherwise, the base may either set solid and be almost impossible to eat, or be too crumbly and fall to pieces. The amounts therefore have to be measured more carefully in this case: using scales and a measuring jug or measuring spoons is a sensible way of going about it.



the interval between 100 g and 200 g is split into four equal parts; so each part represents 25 g

175 ml is half-way between 150 ml and 200 ml

Figure 1 *Kitchen scales and a measuring jug*

Is it really necessary to make and specify measurements in this way? Or is it possible to manage with general guidelines and a few kitchen utensils, as was done in mediaeval times?

If you have ever tried to follow an informal recipe, you will know that they often rely on a certain amount of training and past experience to work well. They are difficult to follow if you are not familiar with the techniques, or what the end product should look or taste like. For example:

- How thinly should pasta be rolled?
- How soft is a 'soft' dough?
- How big is a 'cup'?
- Does 'a teaspoon of grated lemon rind' mean a level teaspoon, a rounded teaspoon or a heaped teaspoonful?

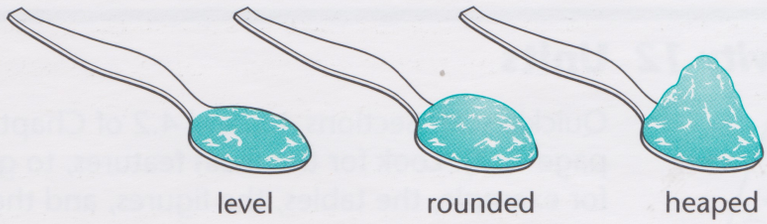


Figure 2 *Spoonfuls*

For certain recipes, such as the biscuit base mentioned earlier, an understanding of these terms can make all the difference between an edible and a completely inedible product. To add to the confusion, some of the words represent varying quantities, depending on where you are. For example, an US 'pint' is quite a lot smaller than an English 'pint'.

For dry ingredients, such as flour, in the UK 'a tablespoonful' implies that it is 'rounded' (that is, that there is an equal amount above and below the rim of the spoon). In the USA, the equivalent amount is described as 'two tablespoons', and they are assumed to be level ones. Recipes expressed in this kind of measure can therefore be very confusing. It is much simpler to use a system of measurement that everyone has agreed upon.

2.3 The metric system

As was noted in Chapter 1, two systems of measurement are currently in use in the UK: the imperial system and the metric system. Although much of the metric system was adopted for use in the UK in 1965, we do not use it in every circumstance. For example, road signs are still in miles, not kilometres.

Many people still remain more familiar with dealing with imperial measurements, such as feet and inches, gallons and pints, and pounds and ounces. Since they can work perfectly well with the imperial system, they find it difficult and time-consuming to shift over to the metric system. It is much easier to stick to the old familiar system, in which they may have a much better 'feel' for the actual sizes of the different units.

Nevertheless, as was said at the end of the last section, life would be much simpler if everyone were to use the same system. For this reason, people working in mathematics, science and technology have agreed to use the metric-based units of the *Système International* (SI) recognised throughout the world. This system has fewer units, and since nearly all its multiples and fractions are based on tens (except time!), it makes calculation easier than in the imperial system.

Activity 12 Units

pages 137 to 142

Quickly scan Sections 4.1 and 4.2 of Chapter 5 of the SGSG (starting on page 137). Look for the main features, to get a 'feel' for what is covered: for example, the tables, the figures, and the box on page 140. Have a go at the Activity Break on page 141.

If you feel uncertain about the use of SI units, read through the whole of these two sections in detail.

Make some notes on the SI system.

If you are not familiar with the common SI units and their symbols it is worth copying them into your personal dictionary.

The metric units used most often in cookery and everyday life are shown in Table 3. The final column gives some examples of items that might be measured in the appropriate unit.

Table 3 Everyday metric measurements

Character measured	Unit	Abbreviation	Example
mass	milligram	mg	the mass of a grain of sugar is about 1 mg
	gram	g	a rounded tablespoon of sugar is about 30 g
	kilogram	kg	the mass of a bag of sugar is 1 kg
volume	millilitre	ml	a medicine spoon holds 5 ml
	centilitre	cl	a standard wine bottle holds 75 cl
	litre	l	a carton of fruit juice usually contains 1 litre
length	millimetres	mm	a 1p coin is just over 1 mm thick
	centimetres	cm	a 1p coin is about 2 cm wide
	metres	m	a standard door is about 2 m high
	kilometres	km	5 km is about 3 miles

Mass and weight

You may have noticed that instead of the everyday word 'weight', the SGSG and the text above talk about 'mass'. There is a subtle distinction, though it will not affect your calculations.

- Your mass is the amount of matter in you (for example, in grams or kilograms). This obviously does not change wherever you are in the universe.
- Your weight, however, depends on the pull on you (gravity) of any body near you, such as the planet you are on. So weight changes with position.

Don't expect to grasp a fine point like this straight away. Not every detail explained in the module has to be understood immediately! You'll probably come across this distinction later in your studies, when you'll have more opportunity to think about its significance.

(You doubtless remember seeing astronauts bouncing about on the moon because they 'weighed' less on the smaller body. In space they seem to be 'weightless', although their mass is still the same.)

Scientists do have a measure for weight, and a way of taking the difference into account, but you can quite safely ignore it at this stage. Unfortunately, non-scientists have the everyday habit of using 'weight' when what they have in mind is amounts (mass).

So when you see a measurement called 'weight' and quoted in grams, kilograms or similar units (or when you have converted from imperial units), it is perfectly safe to use this in your calculations. In your own mind, just *think* of it as a *mass*!

2.4 Estimating

To help you get a 'feel' for the metric system, make a determined effort to measure things metrically: for example, in recipes, DIY jobs, on journeys, in the garden, and so on. Look at the quantities given on signs and packet labels, and try to remember the feel or look of the amount inside.

If you can visualize the size of the different units it helps you to check that your answers to problems are sensible. The more you use the metric system practically, the more comfortable you will feel with it, and the easier it will be to extend your knowledge to the SI units used in science and technology.

Activity 13 Estimating for yourself

Estimate and then measure the following items, using metric units. Record your results in a table in your Study Folder.

(a) The mass of an apple in grams.

(b) Your mass in kilograms.

(c) Your height in centimetres.

(d) The length of your handspan.

(e) The width of your thumb in millimetres.

(f) The capacity of a mug in millilitres.

(g) The capacity of a milk bottle in litres.

(h) The dimensions of a room in metres.

Then try the activity again, this time using slightly different objects: a different apple, a friend's measurements, and so on. Since you are making a comparison against a measure you now know, you should find that estimates in your second group are closer than those in the first group.

Check that your table has a title, and clearly labelled columns, and that you have included the units. If you need more practice in estimating metric quantities, extend the table and try some more examples of your own. Part of a similar table is shown as Table 4 (overleaf).

Remember to think 'mass' when you want to know 'How much is there of something?'

Table 4 Comparing metric estimates and measurements of everyday objects

Item	Estimate	Measurement
apple	50 g	45 g
my mass	50 kg	58 kg
height	150 cm	163 cm
handspan	15 cm	21.2 cm

Once you have a firm grasp of the metric measurements of some familiar objects, it becomes possible to make estimates of other, less familiar objects, and so build up a range of sizes and units for which you have a mental image. This is the secret of winning 'guess the weight of the cake' competitions, but, more seriously, it will help you to make sense of measurements and give you a real 'feel' for size that will stand you in good stead in future studies.

Activity 14 A sense of suitable units

Suggest suitable metric units for measuring the following quantities.

(a) The distance from your home to the nearest city.

(b) The mass of fresh fruit bought in a supermarket.

(c) The thickness of rolled-out pastry.

(d) The capacity of a mixing bowl.

(e) The mass of a jar of jam.

(a) kilometres

(b) kilograms

(c) millimetres

(d) litres

(e) grams

If you feel that you need more practice with the metric system make a note in your Study Diary, so that when you plan your next study week you can allow time to try more activities similar to those above (perhaps of your own devising).

2.5 Converting between measurement systems

If you draw a line one inch long and then measure it in centimetres, you will find that:

1 inch is equivalent to just over 2.5 cm

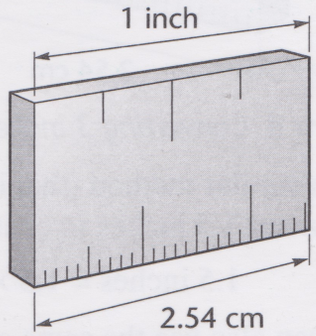


Figure 3 *An inch*

The modern standard inch is now defined as exactly 2.54 cm.

This is often written as:

$$1 \text{ inch} = 2.54 \text{ cm}$$

which is read as 'one inch is equal to two point five four centimetres'.

'Per' can be thought of as 'for every'; for example, per cent (%) means 'for every hundred'.

You will sometimes see:

$$2.54 \text{ cm/inch}$$

which is read as 'two point five four centimetres per inch'.

This second example is an instance of a *conversion factor*, which can be used to convert any measurement in inches to centimetres.

For example: convert three inches to centimetres, rounded to 1 decimal place (see Figure 4).

$$3 \text{ inches} = 3 \times 2.54 \text{ cm} = 7.62 \text{ cm} = 7.6 \text{ cm to 1 d. p.}$$

pages 349 and 350

Incidentally, were you happy with the task of 'rounding to 1 decimal place'? If not, read through the boxes on rounding in the SGSG to remind yourself of the most commonly used methods. If you are not confident about using them, work through the whole section 'Decimal places and significant figures', which begins on page 349.

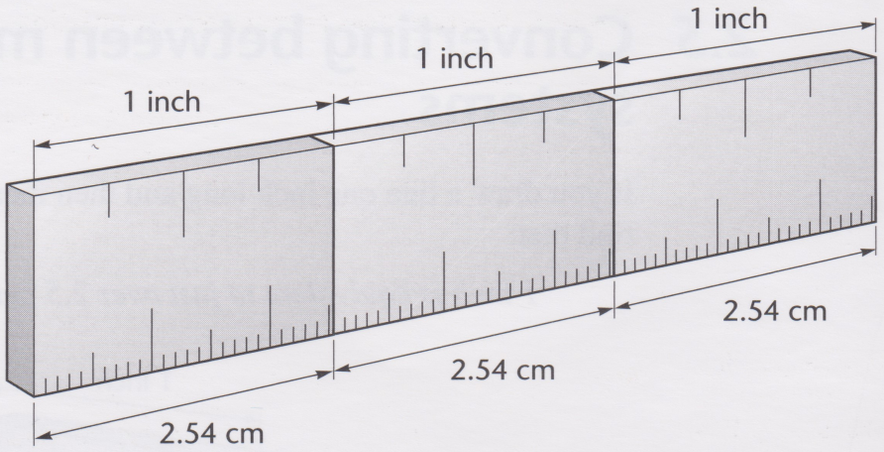


Figure 4 *Converting 3 inches to centimetres*

Use a similar method (that is, multiplying the number of inches by 2.54 cm) to convert 1.5 inches to centimetres.

$$1.5 \text{ inches} = 1.5 \times 2.54 \text{ cm} = 3.81 \text{ cm} = 3.8 \text{ cm to 1 d. p.}$$

You can also use the same conversion factor, in a slightly different way, to convert centimetres into inches.

For example: convert 15 cm into inches.

Knowing that 1 inch is equal to 2.54 centimetres, you need to find how many lots of 2.54 there are in 15. So, divide 15 by 2.54:

You may know from the SGSG that $\simeq$ means 'approximately equals'.

$$15 \text{ cm} = 15 \div 2.54 \text{ inches} \simeq 5.905 \text{ inches} = 5.9 \text{ inches to 1 d. p.}$$

Now, to check that you have the right answer, you can multiply 5.9 by 2.54! This should come to approximately 15. It is always worth checking an answer: it is all too easy to press the wrong button on a calculator or miss a decimal point. An alternative way of checking is to do a quick estimate first: this helps to prevent gross errors. (See page 134 of the SGSG for an example of this approach.)

page 134

Another way of thinking about it is that the conversion factor for converting cm into inches is

$$\frac{1}{2.54} \text{ inches/cm}$$

The reciprocal of any number is that number divided into 1.

Mathematically, this is called the 'reciprocal' of 2.54.

So:

$$15 \text{ cm} = 15 \times \frac{1}{2.54} \simeq 5.9 \text{ inches}$$

Table 5 shows some useful cookery conversion factors. Instead of 'weighing' (finding the mass) it is often convenient to measure out certain ingredients by the space they take up in a vessel: that is, by their volume. The metric unit for measuring volume is the litre. For cookery, informal measures like cupfuls (based on the capacity of a vessel) are just as efficient as scientific ones.

Table 5 Conversion factors for quantities commonly used in cookery

	Informal measurements	Metric equivalent
volume (of contents, that is, capacity of container)	1 cup(ful)	225 ml
	1 teaspoon(ful)	5 ml
	1 tablespoon(ful)	15 ml
mass	1 rounded tablespoonful (e.g. flour or sugar)	28 g
volume (of contents, that is, capacity of container)	1 fluid ounce	28.5 ml
	1 pint (or 20 fluid ounces)	0.57 litres
mass	1 ounce (1 oz)	28.35 g
	1 pound (1 lb) (or 16 ounces)	0.4536 kg
length	1 inch	2.54 cm

A rounded tablespoonful of these items has a mass of about 28 g. This is not true for all ingredients.

Table 5 can now be used to convert some of the quantities in the lamb stew recipe to metric units (see Table 6).

Table 6 Metric conversions for lamb stew

lamb	2 lb	= 2 × 0.4536 kg	= 0.9072 kg
cubes	2 inches	= 2 × 2.54 cm	= 5.08 cm
stock	2 cups	= 2 × 225 ml	= 450 ml
white wine	1 cup	= 1 × 225 ml	= 225 ml
lemon juice	2 tablespoonfuls	= 2 × 15 ml	= 30 ml

The problem with converting from imperial to metric is that none of the conversion factors is a 'nice round number' and so frequently conversions do not produce quantities that can be practically measured, especially using ordinary kitchen equipment.

2.6 Practical measurements

Activity 15 How well can you measure?

How closely do you think you can measure, using your own kitchen equipment? You will need to look at the actual equipment carefully.

(a) To the nearest, how many grams can you read on your kitchen scales?

(b) To the nearest, how many millilitres can you read on your measuring jug?

(c) What do you think affects how well you can use such equipment for measuring?

Your equipment can probably be read to:

(a) 25 g

(b) 25 ml, or possibly 10 ml

'Scale' is used here to indicate the equipment itself.

If you are using a balancing scale or an electronic scale, you may be able to measure more closely than this.

(c) In general terms, the factors that affect how well any measuring equipment can be used include:

- how well the equipment is made and maintained
- the number of divisions on any scale
- how carefully the equipment is used, and how carefully any measurement is read off.

Here, the 'scale' is the marked and numbered line from which you take your reading.

Whatever kitchen equipment you use, you are unlikely to be able to measure the 907.2 g of lamb apparently needed for the lamb stew. For practical purposes, the quantities should be rounded to amounts that can be measured easily. Look at the scale shown in Figure 5. It is marked in major intervals of 25 g.

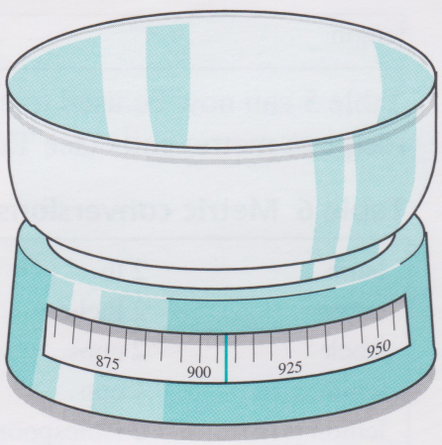


Figure 5 *Kitchen scale*

You can see that 907.2 g is closer to 900 g than to 925 g.

So, a sensible amount of lamb to use is 900 g, cut into 5 cm cubes.

Activity 16 Converting recipes

The following recipe was issued by the Stork Margarine Company during the Second World War.

Update it to metric measurements and round off the measurements to practical quantities.

Savoury rice for four

- $\frac{1}{2}$ lb rice
- $2\frac{1}{2}$ oz grated cheese
- 1 small onion, finely chopped
- $\frac{1}{2}$ pint of milk
- 1 oz margarine
- salt and pepper

Adapted from Croft (undated) *The Stork Wartime Cookery Book*

Recipes in which quantities are given in both metric and imperial quantities often advise you to follow one set of measurements and not to mix the two.

Write a short paragraph in your Study Folder explaining why you think this advice is given.

Using the conversion table (Table 5):

(a) $\frac{1}{2}$ lb = $\frac{1}{2} \times 0.4536$ kg = 0.2268 kg = 226.8 g

so to the nearest 25 g, $\frac{1}{2}$ lb = 225 g

(b) 1 oz = 28.35 g

so, to the nearest 25 g, 1 oz = 25 g

(c) 2.5 oz = 2.5 × 28.35 g = 70.875 g

so, to the nearest 25 g, 2.5 oz = 75 g

(d) $\frac{1}{2}$ pint = 0.5 × 0.57 l = 0.285 l

so, to the nearest 10 ml, $\frac{1}{2}$ pint = 290 ml

The metric recipe is therefore:

Savoury rice for four

- 225 g rice
- 75 g grated cheese
- 1 small onion, finely chopped
- 290 ml milk
- 25 g margarine
- salt and pepper

The amounts indicated by the metric and imperial measurements do differ slightly, because the metric conversions have been rounded off to practical measurements.

In certain recipes, some measurements may be adjusted slightly so that the consistency of the mixture remains the same. For example, if a recipe contains several dry ingredients in which the metric measurements have

all been rounded down, the total quantity of dry ingredients produced may be substantially less than the imperial equivalent. Then, although the metric equivalent of the liquid required might be, say, 150 ml, in practice 125 ml would be specified in order to maintain the balance of wet and dry ingredients. It is therefore advisable not to confuse the two different sets of measurements.

A dictionary will help you to understand the use of 'accuracy', 'precision', 'error' and 'uncertainty', and give you a feel for some of the difficulties.

An aside on 'accuracy'

You may have noticed that this text uses expressions such as 'how closely' and 'how well', when you might have expected 'how accurately'. But the meaning of the word 'accurate', and the associated word 'precise', as used in everyday speech may vary considerably, depending on the context. They have different meanings in the different sciences and disciplines!

When a mathematician uses the word 'accurate' it has a different interpretation from that understood by a scientist.

You may have an understanding of the mathematical uses of such words, and a view of an 'error' as a mistake: that is, something avoidable. In science and technology, however, the idea of error (or uncertainty) is more complex.

Activity 17 Making notes

Study skills

Make sure that any new words or symbols have been added to your dictionary.

pages 51 to 53

In the 'notes' section of your Study Folder, make some notes summarizing measurement and the metric system. Do so in your own words and in a form that you can understand and read easily. You can use diagrams or tables, as well as written statements. Try to identify the main points of this section.

Look again at the box on page 51 of the SGSG, 'What are note-making skills?', and at Section 5.3, which follows the box.

What do you think are some of the benefits of making notes like this? Write a paragraph in your Study Folder outlining the main advantages. You may be able to think of some disadvantages too! The main thing to absorb is that you need to develop strategies of your own.

What you include in your notes depends on your past experience of these ideas. If you can already work confidently with the metric system, you may not need to include much more than a few details on the purpose and accuracy of the measurement and on how to round measurements off. If you are unfamiliar with the metric system, you could include:

- the names of the different units
- the conversion factors between the different metric units and the imperial units for the same quantity
- examples to remind you of the size of the different units and of how to convert from one unit to another
- diagrams to remind yourself how to round numbers off
- any special cases you need to remember.

If you include page references as well, you can check the text quickly should you need more detail later on.

Making notes gives you a permanent record of the key points, which you can use for reference throughout your studies. It is often quicker to go back through your own summary notes than through the original text. Putting ideas into your own words helps you to understand and remember them too. If you use a spray diagram, you can also see how the different ideas link together, giving you an overall picture of the topic.

The main drawback to making summary notes is the time it takes. However, spending time now may save you time in the future.

2.7 Using mathematics

One advantage of writing down a recipe is that it can be adapted to cater for different numbers of people. For example, suppose a party of 12 were to order lamb stew. Since the metric recipe in Section 2.5 is suitable for six people, all the measurements for the ingredients would have to be doubled to give the amount needed for a party of 12. Similarly, if you wished to adapt the recipe for two people, the quantities would all be divided by three (see Table 7).

Table 7 Adapting recipe quantities

Ingredients	For 12 people	For two people
boneless stewing lamb	900 g × 2 = 1800 g	900 g ÷ 3 = 300 g
chicken stock	450 ml × 2 = 900 ml	450 ml ÷ 3 = 150 ml
onions, small	2 × 2, so 4 onions	$\frac{2}{3}$ (two-thirds) of one onion or 1 *smaller* onion
fresh herbs	half-teaspoon of each	$\frac{1}{6}$ to $\frac{1}{3}$ (a sixth to a third) of a teaspoon of each
spice	half-teaspoon of each	$\frac{1}{12}$ (one-twelfth) of a teaspoon of each
salt to taste	salt to taste	salt to taste
white wine	2 × 225 ml = 450 ml	225 ml ÷ 3 = 75 ml
eggs	2 × 2, so 4 eggs	$\frac{2}{3}$ (two-thirds) of an egg or 1 small egg
lemon juice	2 × 30 ml = 60 ml	30 ml ÷ 3 = 10 ml

Remember to say $\frac{2}{3}$ as 'two thirds' and $\frac{1}{12}$ as 'one twelfth'.

Notice that some of these measurements would be very difficult to measure in practice, so sensible alternatives are chosen instead. In place of '$\frac{2}{3}$ of an egg', '1 *small* egg' might be used, while '$\frac{1}{12}$ of a teaspoon' would probably be described as 'a pinch'.

In general, if you want to adapt a recipe for a given number of people, first find the amount of each ingredient that would be needed for one person. Then work out the quantities for the whole group by multiplying these amounts by the number of people in the group. Finally, round off these values to an amount that can be easily measured in practice.

For example, suppose you have a recipe for eight people which requires 250 g of flour and one egg. How much flour and how many eggs would you need for 10 people?

1 person requires $280 \div 8$ g $= 31.25$ g

so, 10 people require 10×31.25 g $= 312.5$ g

When rounding off to the nearest 25 g, you could use either 300 g or 325 g. It would be sensible to make the choice of rounding up or down on the basis of quantities of the other ingredients. For example, if most were rounded up, then use 325 g.

The point here is that mathematics gives you guidance, but you need to make sensible decisions!

In this case, $\frac{1}{8} \times 10 = 1.25$ eggs are needed. So, here it might be better to round down, using 300 g of flour and one *large* egg. (Of course, it is also possible to produce 'a quarter of a raw egg' by breaking it, mixing well and then taking a quarter of the liquid! But what will you do with the rest? Or could you make up the extra liquid volume needed by substituting a little milk?)

Notice that when you scale up a recipe, the amounts of all the ingredients are changed in the same proportion. They are all, for example, tripled or halved. However, the cooking temperature usually remains unchanged, and although the cooking time may change slightly, it does not change to the same extent as the ingredients. There are good scientific and mathematical reasons why this is so, but they are not going to be considered in this module.

Activity 18 The more the merrier

Adapt the following metric recipes.

(a) Savoury rice, in Activity 16, for 11 people.

(b) Modern lamb stew, on page 16, for nine people.

Round up the calculations to produce a recipe that people using ordinary kitchen equipment could follow.

(a) The recipe for savoury rice is for four people. So, to find the quantities for 11 people, divide each quantity in the recipe by four and then multiply that amount by 11. Rounding off the measurements gives the following recipe.

pages 303 to 304

Savoury rice for 11

625 g rice	$(225 \div 4 \times 11 = 618.75 \simeq 625)$
200 g cheese	$(75 \div 4 \times 11 = 206.255 \simeq 200)$
825 ml milk	$(300 \div 4 \times 11 = 825)$
75 g margarine	$(25 \div 4 \times 11 = 68.75 \simeq 75)$

This is a mixed calculation – see Maths Help for more explanation.

(b) The recipe for lamb stew is for six people. So, to find the quantities for nine people, divide each quantity in the recipe by six and then multiply that amount by nine. (Alternatively, since 9 divided by 6 is 1.5, you could just multiply each quantity in the original recipe by 1.5.) The following recipe is the result.

Lamb stew for nine

- 1.35 kg lamb
- 675 ml stock
- 3 onions
- $\frac{3}{4}$–$1\frac{1}{2}$ teaspoons of each herb
- 350 ml wine
- 3 eggs
- 50 ml lemon juice
- $\frac{3}{8}$ (three-eighths) of a teaspoon of each spice

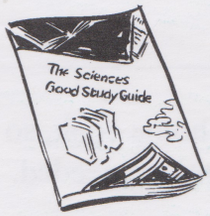
2.8 Interpreting the answer

In the examples above you have seen how mathematics can help solve a catering problem. That is, it can guide the decision as to how much of each ingredient is needed for a recipe for a given number of people. However, before you can use mathematics in a practical way like this, you often have to simplify the problem by making certain assumptions. In this case, one assumption has been made – that everyone will eat the same amount.

When you have worked out a mathematical answer, it is important to spend a few moments reflecting on the nature of the problem, and on how it relates to:

- the assumptions you have made
- the methods you have used
- the answers you have obtained.

Does your answer 'feel' sensible and realistic? For example, in the cases above, measurements were often rounded off in order to use the results practically. It is worth considering whether you could also use the same techniques in other situations. Would this method work equally well for any recipe, and any size of group?



page 88

The process of using mathematics to solve practical problems can be thought of as a cycle. Look at Figure 4.1 on page 88 of the SGSG for a representation of this cyclic process.

Activity 19 Possible problems

Think back over the techniques you used in Activity 18. Write out a method or rule that would work for any recipe and any number of people.

Would you use this method to work out the amounts for a group of any size? Write down any difficulties that you might meet in adapting the recipe for groups of different sizes.

A general rule would be:

Take each ingredient quantity in turn, divide by the number the recipe is written for, and multiply by the number of people to be fed. Then round off the results into practical measures.

You have already seen the problems that can arise in trying to round off the measurements in a practical way. For example, if you decided to make lamb stew and savoury rice for one person, you would need a third of an egg and a quarter of a small onion!

So, sometimes scaling down recipes just is not worthwhile. In such cases, it is better to make a larger quantity and then store the excess.

The mathematics are a tool for the cook to use to aid the decision-making process.

Scaling up recipes to cater for large groups can create problems too.

Suppose you were trying to calculate the quantities required for a large group of, say, 100 people. Would you, as the chef in charge, use the method in Activity 19?

Well, in theory, yes, you could. The method would give you the quantities you need for 100 people. But, in practice, you probably would not use this method. When catering for large numbers, you still have to make sure that there is enough food for everyone, but at the same time, you want to make sure that cost and wastage are kept to a minimum. A recipe designed for four people may allow generous portions, from which there is some food left over. Scaling the recipe up can then result in a considerable waste of both food and money. Within a large group of people, some people may even take smaller portions or none at all. Therefore, a chef catering for large numbers often uses rules of thumb (based on experience) such as:

> Allow 150 g of lamb per person for up to 10 people; for more than 10 people, allow 125 g per person.

The purpose, or reason for making a measurement is an important aspect to consider.

The chef's purpose in measuring is different from that of the home cook, so different assumptions are made in order to decide on the quantities needed.

Activity 20 Feeding 100 hungry people

How much lamb would you need to make mounchelet for a mediaeval feast for 100 people, if you used the chef's rule above?

How much lamb would you need if you scaled up the original recipe directly?

How much lamb do you save if you use the chef's rule?

Write down your calculations, explaining your working carefully, so that a fellow student could understand it.

The chef's rule allows 125 g of lamb for each person.

Total amount of lamb required is 100×125 g = 12 500 g = 12.5 kg

The original recipe allows 150 g of lamb for each person.

Total amount of lamb required is 100×150 g = 15 000 g = 15 kg

Therefore, using the chef's rule saves 2.5 kg of lamb.

You will notice that the answer to Activity 20 was set out in a logical, clear way. Assuming that you wrote out your answer, compare it with ours.

Would your response be comprehensible to a friend or fellow student?

If not, you would be well advised to read through Section 5 of Chapter 4 of the SGSG, 'Expressing yourself mathematically', beginning on page 112. It shows that problems in mathematics require more than producing 'right answers'. Solutions have to be written out in a way that can be clearly understood by others.

pages 112 to 115

2.9 How are you getting on?

Activity 21 Reflecting

Study skills

At the end of a chapter, or section of work, it is a good idea to look back on the studying you have done and the new things you have learned. This will not only raise your morale, when you realise how much you have learned already, but also help to reinforce the learning.

Summarize what you have learned from this chapter about measurement.

Remember from the end of the last chapter that a summary can include notes, tables and diagrams.

Activity 22 Taking stock of study skills

Study skills

On a new page in the notes section of your Study Folder, write a review of your study so far. Using the questions below as a guide, try to identify when you study well and what areas of your studying you would like to improve. Write down any changes that you would like to make before studying the next chapter.

First, look back over your Study Diary.

- Did you find long or short study sessions more productive?
- Did the time of day make a difference?
- Were there times when you found concentrating difficult, and if so, can you think why?
- Can you identify good times to work, what kind of activities to do at which times?
- Did this chapter take more, or less, time than you thought it would?

Now, look back over your notes.

- Do they summarize all the main points?
- Can you still understand them?
- Do you need to include any more details in your notes, or would they be clearer if you left some details out?
- Would an alternative form of note-taking work better for you?

Next, consider your learning.

- Did you work through the activities and compare your responses with those given?
- When you found an activity difficult, did you ask someone for help or follow up the extra suggestions (by trying the practical activities suggested in the metric section, for example, or by reading parts of the SGSG)?

Finally …

- Read carefully through the box at the end of the chapter. Identify any area where you feel you need more practice or help, and decide what you are going to do about it.

This process of spending a few minutes thinking about what you have achieved and what difficulties you have encountered is well worth following at the end of each chapter.

Learning Outcomes

You should now understand that:

- quantities can be measured using different instruments and different units
- communication is made simpler if everyone uses the same measuring system, namely the metric-based SI system
- the accuracy of a measurement depends on the tools used and the purpose of the measurement
- it is important to reflect on the meaning and credibility of any answers you obtain from a calculation.

You should now be more able to:

- estimate and measure lengths, masses and volumes (capacities) in metric units
- perform basic calculations using decimals, fractions and percentages
- convert non-standard (imperial) units into metric units
- round off the results of calculations to a practical level of precision
- keep a Study Folder of your notes and activities
- reflect periodically on your own learning and progress, and consider practical ways of improvement.

CHAPTER 3 ON THE ROAD

Neddie Seagoon: How far is it to the valley?
Major Bloodnock: Roughly sixty miles.
NS: I know it's roughly sixty miles, but what is it exactly?
MB: Seventy miles.
NS: We'll go roughly, it's ten miles shorter.

Spike Milligan (1958) 'The Mummified Priest', *The Goon Show*

3.1 Introduction

This chapter looks at some more of the important issues in measurement through the topic of travelling by road. While working through the chapter, you will have an opportunity to practise a range of different study skills. It involves learning to make use of information given in a variety of forms, such as:

- audio drama
- graphs
- extracts from technical guides
- tables
- verbal instructions
- maps
- charts.

Above all, it involves you being an active learner: trying things out, thinking about ideas, and making your own notes. This Study Book can guide you through the process, but only you can do the learning.

Health warning!

Getting organized and planning use of time are vital to effective studying. But there never seems enough time to do everything as well as you might like. Do not worry about this: just do as much as you can in the time you have available.

As you become a more experienced student, you will know your own learning needs better and be able to decide where you need to put in a lot of time and effort, and where you can afford to skim over things.

At this stage, you are still learning how to learn. You will undoubtedly make mistakes, perhaps by rushing over something that proves vital, or taking too long to do something you did not really need to do in so much detail. But these mistakes help you to learn about yourself. They are part of the process, so when they happen, think of them as a positive gain and not as something to become dispirited about.

Activity 23 Planning study

Study skills

pages 8 to 14

Now you have experience of working through two chapters, you will know how important *planning* is to successful studying. Skim through this chapter to identify the separate sections and what the activities ask you to do.

Section 3 of Chapter 1 of the SGSG is about the importance of organizing your study. Re-read the section now and work through the Key Points box on page 14.

Now apply what you have learned from the SGSG by making a plan of where and when you are going to study the sections of this chapter. Make a note of what equipment you might need, and estimate how long you intend to study. The Study Diary section of your Study Folder would be an appropriate place to keep your plan.

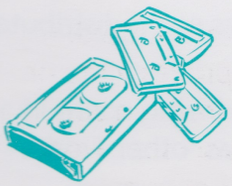
The notes are very personal; you might have included 'find a ruler', or 'need to do this when fresh'. As you work through the chapter, add to these notes. At this stage you may not be sure how long things are going to take you, but try to set times nevertheless. Keep a record of what actually happens, so next time you plan a chapter you will have a better idea of how much time to set aside, or of how best to use the time you have available.

3.2 Measurement on the road

One of the main uses of roads is the transportation of goods by lorry. In the United Kingdom (and many other countries) this use is highly regulated. These regulations deal with the sizes of lorry and load (lengths, widths and axle weight) and also include restrictions on speed and on the length of time a driver may work, including loading, driving and rest time. One of the enforcement agencies for lorry legislation is the Police.

Activity 24 Drive time 1

Study skills

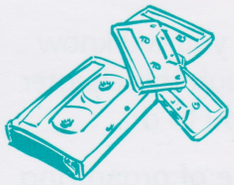


Listen to Side 1, Track 2 of the audio-cassette. It opens with some information given in dramatic form. Listen carefully. At the end of the first section you are reminded of some distances that arise in the drama. You are then asked to switch off the audio-cassette and do some work for yourself.

Make sure you keep your notes; you will need them later. Label the notes in some way so that you will be able to find them easily. For example, use the activity number and title and or a heading such as 'Notes on reported distances' or 'Why distances not the same'.

Activity 25 Drive time 2

Study skills



Listen to the next section on the audio-cassette. Again there is information given in dramatic form. If your tape recorder has a counter, note the number at the beginning of each sequence so that you can get back to the beginning easily. Make brief notes as you listen to the audio-cassette.

At the end of the sequence, you are asked to study the driving legislation given below. First, have a quick read through to get a sense of the type of text you are dealing with, then read in more detail. Make a note of how long you spend reading through the extracts from the driving regulations.

It is unlikely that you will be familiar with all of what you read in this text. So 'studying' the text does not mean painstakingly struggling to understand all of it, but just getting a 'broad idea' of what is involved.

Extracts from driving regulations

The actual legislation is written in legal language, which is very difficult to follow, so the Department of Transport has produced *Goods Vehicle Drivers' Hours and Tachographs: EC National and International Rules* (1984), which is supposed to make things more comprehensible to those having to keep and enforce the law.

The following are extracts from this guide.

Now the European Union.

European Community (EC) international and national rules

These rules apply to most goods vehicles over 3.5 tonnes permissible maximum weight.

Daily driving limit

A driver must not drive for more than 9 hours in a day, but this may be extended to 10 hours twice a week.

The daily driving limit means the period spent at the wheel between any two daily rest periods or between a daily rest period and a weekly rest period. Driving off the public road does not count as driving time.

Continuous driving limits and breaks

After four-and-a-half hours' driving, whether continuous or accumulated, a driver must take a break of at least 45 minutes, unless he begins a daily or weekly rest period.

This break may be replaced by breaks of at least 15 minutes each, distributed over the driving period or immediately after this period.

For break purposes waiting time and time not devoted to driving spent in a vehicle in motion, a ferry, or a train, shall not be regarded as 'other work'.

During a break a driver must not drive or do other work.

Breaks may not be regarded as daily rest periods.

Record keeping – tachographs

Drivers subject to the EC rules must use tachographs to record their hours of driving, other work and rest periods.

Recording hours of driving, work and rest

Recordings will start when the chart is placed in the tachograph. Drivers must make sure that it is working continuously and correctly while they are responsible for the vehicle. In particular they must operate the mode switch so that the following times are recorded separately and clearly on the chart:

- driving time
- other periods of work and of attendance at work
- breaks from work and rest periods.

Department of Transport (1984)

pages 36 to 39

This activity should remind you of the need to vary how deeply you study particular text and the time you spend on it. Here you need not get bogged down in the details: you just need to understand the gist of what is being said. Chapter 2 of the SGSG has more to say about reading and making notes: read what is said in Section 3.2 about reading speed. You have probably already noted down in your Study Diary the need to read the whole of Chapter 2 of the SGSG in the near future.

So, what is a tachograph? A formal description is:

> A tachograph is a precision indicating and recording instrument closely resembling a conventional speedometer.
>
> It incorporates a clock which must be accurate to ±2 minutes per day.
>
> It records information on time, speed, distance and driver activity in circular graph form, using styli on a waxed paper chart. In use the accuracy is to be ±6 kph for speed and ±4% for distance.
>
> West Midlands Police Driving School (undated)

'±' is said as 'plus or minus'.

'Styli' is the plural of 'stylus', a needle-like pen.

'kph' means 'kilometres per hour'. In SI units this would be written as 'km h^{-1}'.

The first and third sentences provide sufficient technical description for the understanding of this module. In more simple language:

> A tachograph is a device that measures and makes a record of time, speed, distance and driver activity. The record is in the form of a chart.

The rest of the technical description is about the precision required of a tachograph when in use. For example, the clock is only permitted to be a maximum of two minutes fast or two minutes slow in twenty-four hours.

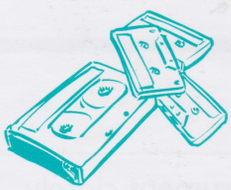
Activity 26 Tachograph chart reading

Look at the tachograph chart (often, for quickness, also known as just 'the tachograph') reproduced in Figure 6, and try to make some sense of it. What measures can you find on it?

The next track of the audio-cassette will explain the key features of the chart, but before you listen to it, have a look at the scale marked on the outer rim (or circumference) of the disc. This scale measures the time, using the twenty-four hour clock. The hours (1 to 24) are marked on the scale and each hour has been divided into smaller intervals. There is also a similar time scale elsewhere on the disc. Can you find it? Work out what each interval represents on both scales.

There are 12 intervals marked in each hour. Since there are 60 minutes in one hour, each interval represents (60 ÷ 12) minutes: that is, 5 minutes. If you look very carefully at the marks on the scale, you can see that every third mark is slightly longer than the others. These longer marks enable you to read off every quarter of an hour more easily. Check that you feel confident about reading these timescales.

Activity 27 Key features of a tachograph chart

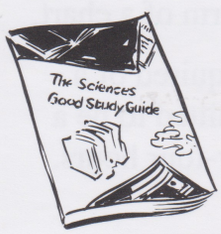


Listen to the next section of the audio-cassette, which explains what information can be read off the tachograph chart shown in Figure 6. The numbers 1 to 5 show the particular sections of the chart referred to in the audio.

You may need to stop and replay this section several times. Noting counter readings will help.

Key

1 Centre section, giving details of the date, the driver and the vehicle.
2 Two timescales, to enable the time of any other part of the chart to be read off.
3 Speed rings.
4 Driver activity lines.
5 Distance track.



page 80

A tachograph chart is complex, giving a great deal of information condensed into a small space. Once you have worked out what each section is about, it is relatively easy to read off the information and see the changes in the pattern of activity of the vehicle and the driver. This is one of the keys to learning how to read any graph or chart. First get a feel for what the chart is about, and then make sure that you understand what each section or part is about.

There is a useful checklist for reading charts and graphs on page 80 of the SGSG. Look at it now.

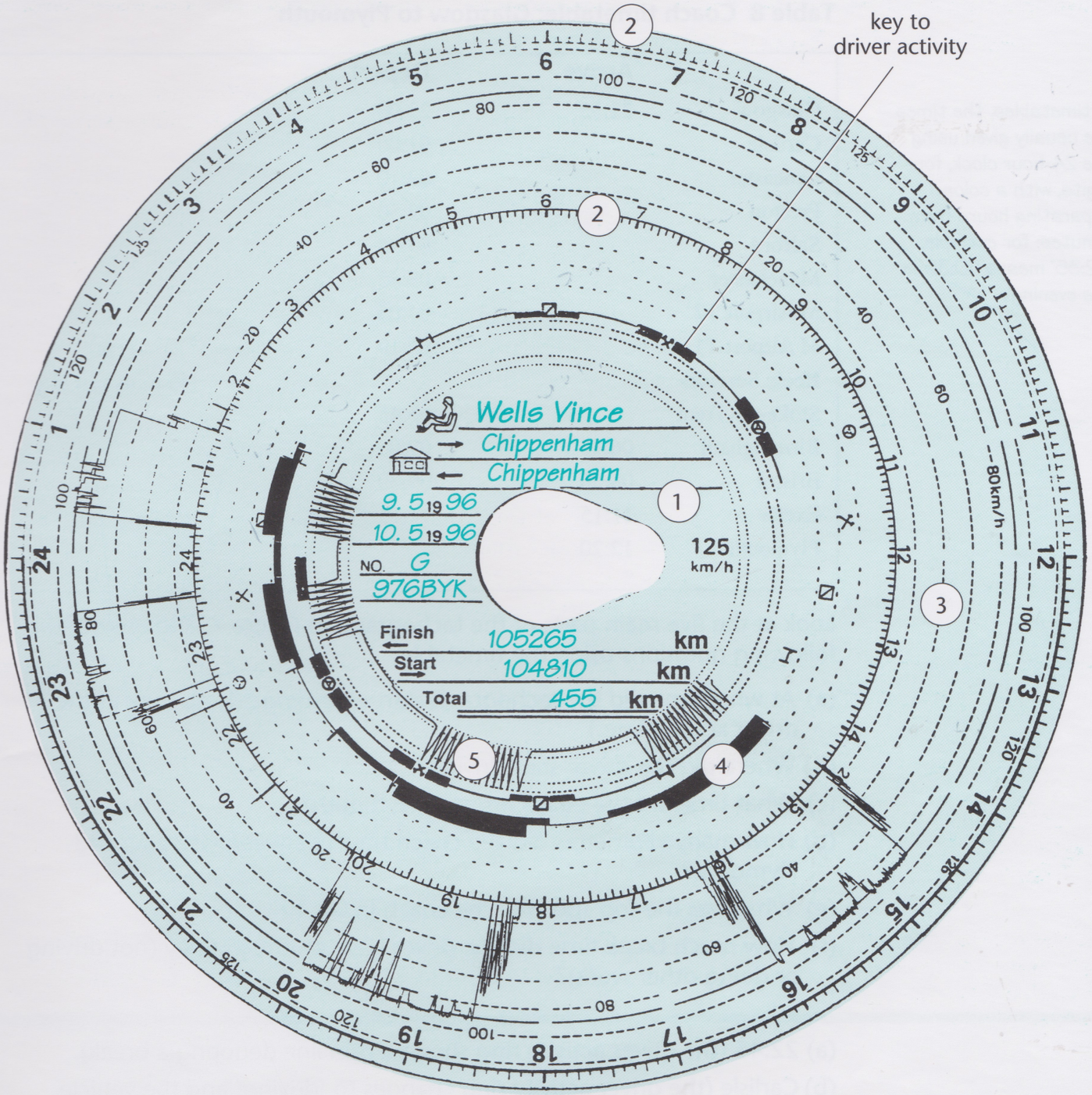


Figure 6 *A completed tachograph chart*

Activity 28 Another tachograph chart

Look at the tachograph chart shown in Figure 7. This is for a different sort of vehicle from the last one. It came from a long-distance coach going from Glasgow to Plymouth; but the format is the same.

Table 8 is taken from the printed coach timetable.

In timetables, the times are usually given using the 24-hour clock, four digits, with a colon separating hours from minutes: for example, '22:35' means '10:35 in the evening'.

Table 8 Coach timetable: Glasgow to Plymouth

	Arrive	Depart	
Glasgow	22:35	23:00	
Carlisle		01:00	
Lancaster		02:10	
Preston		02:50	
Salford		03:35	
Manchester		03:45	
M Airport T2		04:05	
M Airport T1		04:10	
Keele Services			45 mins rest stop
Stoke-on-Trent		05:45	
Birmingham	06:45	07:00	
Bristol	08:50	09:30	
Exeter	11:15	11:15	
Plymouth	12:20		

Look at the five main parts of the tachograph in Figure 7, and answer the following questions using the timetable.

(a) At what time did the tachograph start recording? (Hint: look at the driver activity line.)

(b) Where did the driver start driving?

(c) What time did the coach arrive in Plymouth?

(d) How many kilometres did the coach travel between Glasgow and Plymouth?

(e) What was the top speed of the coach in km/h?

(f) How much break time did the driver have on the journey (not driving or doing other work)?

(a) 22:45 (the driver activity ring shows a thin line denoting a break).

(b) Carlisle (the driver activity ring changes to 'driving' and the vehicle speed is shown).

(c) 12:10 (the vehicle speed stops and so does the driver activity).

(d) 888 km (from the centre section).

(e) Approximately 117 km/h – the maximum is about three-quarters of the way between the 100 km/h and 120 km/h speed rings. (However, 70 mph is approximately 113 km/h, so it might appear that the coach was speeding – but remember that the tachograph has a tolerance of ±6 km/h, so the coach was 2 km/h inside the accurate figure required.)

(f) The breaks were as follows.

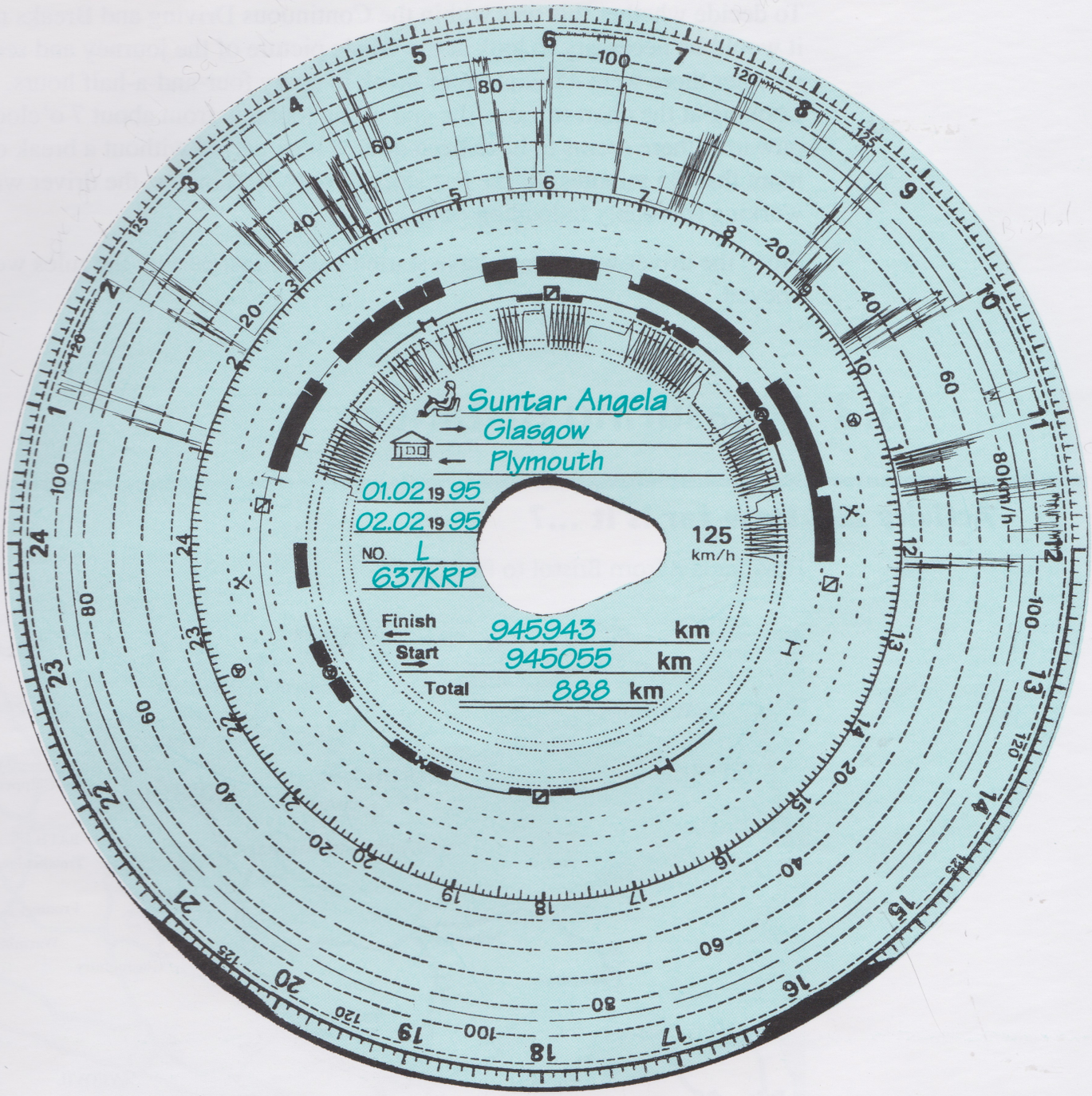


Figure 7 *Coach tachograph chart*

Time of day	Break time
22:45–01:00	2 hours 15 mins (relief driver)
02:20–02:50	30 mins
04:30–05:05	35 mins
05:35–05:50	15 mins
06:40–07:10	30 mins
09:00–09:35	35 mins
Total non-working time	4 hours 40 mins

To decide whether this was within the Continuous Driving and Breaks rules, it would be necessary to look at the whole picture of the journey and see whether there were 45 minutes of break in every four-and-a-half hours. Looking at the chart towards the end of the journey, from about 7 o'clock onwards, there seems to have been quite a long period without a break of more than 35 minutes. At the last stop, of only 10 minutes, the driver was working (probably unloading cases).

Since the driver would then have started a daily rest period, the rules were obeyed.

3.3 Measuring distances

Activity 29 How far is it ...?

How far is it from Bristol to Plymouth?

Figure 8 *Map of south-west England*

There are a number of possible ways of solving this problem. Try to find several different ways of working it out, and keep notes on the process as well as your results.

A small-scale map and a mileage chart from and A-Z are provided, but use your own maps or other sources of information where possible.

Aberdeen												
430	Birmingham											
451	88	Bristol										
451	102	167	Cambridge									
513	106	43	201	Cardiff								
570	169	194	118	233	Dover							
145	291	378	378	393	491	Glasgow						
497	118	117	57	151	73	403	London					
335	87	167	159	188	273	215	185	Manchester				
232	209	300	232	312	350	139	276	136	Newcastle			
381	53	140	84	165	210	286	126	67	159	Nottingham		
485	61	72	92	106	143	365	54	157	253	102	Oxford	
616	203	113	274	159	284	490	214	281	412	255	193	Plymouth
543	128	74	129	122	137	417	76	201	320	162	65	146	Southampton

Figure 9 A mileage chart, showing distance in miles

Table 9 shows a number of different possible answers to 'How far is it from Bristol to Plymouth?' Add your own results.

Table 9 Some possible solutions to Activity 29

Source	Distance	Process or tool
AA mileage chart	125 miles	read off chart
A–Z mileage chart	113 miles	read off chart
Autoroute Plus 1	118 miles	computer program using digital mapping
Autoroute Plus 2	125 miles	another computer program
A–Z road atlas	195 km	paper and map scale legend
AA road atlas	125 miles	map wheel (opisometer)
OU author	115 miles	trip odometer reading
Lorry driver	193 km	odometer reading
Coach tachograph	210 km	interpreting chart

Activity 30 Thinking back

There are several reasons why these distances vary. You have already thought about this problem while listening to the audio-cassette and made some notes. Look at these notes, and see whether you can think of anything else to add. Try to reflect generally on measurement, perhaps thinking back to the activities in Chapter 2 where quantities other than distances were considered.

One student wrote the following notes for Activity 24.

Why distances different?

- *route taken*
- *exactly where started and finished in the towns*
- *different map scales*

and then added, after carrying out Activity 29 and giving it more thought:

- *which units used*
- *which tool used*
- *how carefully measured*

You may have worded your notes differently or included different ideas. The important thing is to have done some thinking and written down your thoughts.

These are the fundamental interlinked measurement issues that recur throughout this module. Measurements of distances will depend upon:

- purpose
- boundaries
- units
- methods, tools and use.

You have met all these measurement issues before, although not necessarily worded in this way.

Purpose

This is fundamental. Why a measurement is being made (that is, what it is to be used for) affects:

- what is measured (the boundaries)
- the units used
- the measuring method and tools
- the exactness required.

To help make this idea clearer, consider two different purposes for measuring the distance between Exeter and Plymouth.

(a) To estimate the time it might take to travel by car for a day out.

(b) To work out the cost of extending the M5 motorway to Plymouth.

In the first example the answer is probably needed only to the nearest half-hour, so the estimate of distance can be very rough. However, for the second example, with motorway building costs running into millions of pounds per mile, the distance needs to be known much more exactly.

Boundaries

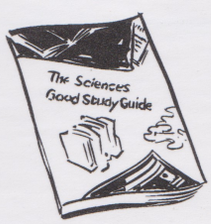
The boundaries of a measurement define where it begins and ends, what is included and what is not. In the solutions to Activity 29, there were slightly different starting and ending places, such as coach stations, a depot and a customer's premises, an Open University Regional Centre and a Tutorial Centre. In other words, they are not strictly comparable, because the journeys had different boundaries depending on their different purposes.

A similar case would be weighing oneself on the bathroom scales. Any loss or gain can only be worked out if the boundaries are the same for the two weighings: that is, on each occasion, clothes and shoes must be either on or off!

Units

Which units are to be used depends again on the purpose of the measurement. If it is made for a purely personal reason, the units to use are the ones that are convenient for you. But if the measurement is to be given to someone else, then it has to make sense to that person. For example, most people in the UK prefer to have distances given in miles (as used on road signs), while people from most other countries prefer kilometres.

Remember that there is international agreement among scientists to use SI units, to ensure that everyone understands each other's measurements and that they are comparable.



pages 137 to 139

Use the index of the SGSG to look up 'SI units'. Read through Section 4.1 of Chapter 5 of the SGSG (starting on page 137), and make sure that you appreciate why SI units are used. You must be able to write out Table 5.1 from memory. (Yes, there are *some* things that you just *have* to learn! Good teaching texts should make it clear which points it is essential to commit to memory.)

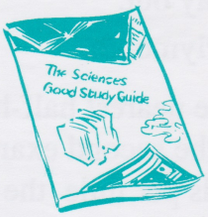
Note particularly that the basic unit of distance in SI is the metre (m).

Comparing distances and identifying variations is only possible when they are expressed in the same units. But in Table 9 there are two different units: kilometres and miles!

Remember to say 'km' as 'kilometres'.

Either all the distances need to be in km, or all in miles, if a comparison is to be made. (Alternatively, the measurements could all be converted into *basic* SI units: that is, to metres.)

Activity 31 Making units the same



pages 365 to 370

Look at each of the distances in Table 9. Some are given in miles and others in kilometres. Your task is to calculate each distance in both miles and kilometres. Write your answers to the nearest mile or kilometre.

Make a table showing your results. To do this you need to use conversion factors, which require some knowledge of fractions and simple formulas. You have already used one form of conversion factor in Chapter 2.

If you do not have this knowledge, or are not very confident about it, work through Section 9 of the Maths Help section of the SGSG. This will give you some basic understanding of formulas and the conventions of algebra. Use whichever method suits you best.

Remember that 'km/mile' is read as 'kilometres per mile'.

The conversion factor for miles to kilometres is 1.609 km/mile to 3 d. p.

So for kilometres to miles, use the reciprocal: that is, $\frac{1}{1.609}$ miles/km

Alternative ways of writing this relationship are:

(a) 1 mile $\simeq 1.609$ km

(b) $M \simeq \frac{1}{1.609} K$

And 'mile/km is read as 'miles per kilometre'.

(where M is the number of miles and K the number of kilometres)

(c) 1 kilometre $\simeq \frac{1}{1.609}$ miles

(d) $K \simeq 1.609 \times M$

As with many conversion factors, the sloping line '/' is used here to mean 'per'. In strict SI, the conversions factors would be written as 'miles kilometre^{-1}'. The sloping line will be used for the rest of this Study Book.

Table 10 Conversion of distances from Bristol to Plymouth, to the nearest mile and kilometre

Source	Miles	Kilometres
AA mileage chart	125	**201**
A–Z mileage chart	113	**182**
Autoroute Plus 1	118	**190**
Autoroute Plus 2	125	**201**
A–Z road atlas	**121**	195
AA road atlas	125	**201**
OU liaison adviser	115	**185**
Lorry driver	**120**	193
Coach tachograph	**131**	210

Check your table. Do you have the same answers? These results have been approximated to the nearest mile or kilometre.
If your answers do not agree with the answers given above, check for

errors in your calculation. If you have kept a written version, with your calculations clearly presented, doing this should be straightforward.

For example:

$1 \text{ mile} \simeq 1.609 \text{ km}$

$\text{so } 1 \text{ km} \simeq \frac{1}{1.609} \text{ miles or } 1 \div 1.609 \text{ miles}$

$193 \text{ km} \simeq \frac{193}{1.609}$

$\simeq 119.950 \text{ miles}$

$\simeq 120 \text{ miles (to the nearest mile)}$

pages 112 to 115

Notice how these calculations were laid out. (The alternatives shown are just different ways of writing the same thing. Use whichever is easiest for you). It is worth getting into the habit of writing out the stages of the calculation, even when you use a calculator. It helps prevent errors, makes calculations easier to check for your tutor, and in an exam can earn you some marks, even if your final answer is wrong. (Section 5 of Chapter 4 of the SGSG 'Expressing yourself mathematically' has more to say about this topic.)

Summarizing data

Mode

'Data' means items of numerical information.

If you were asked to give just one distance to summarize all the information in the table above, what would you say? You might just look down the set of data and pick the value that occurs most often.

In the set of data in Table 10 this is easy to spot: 125 miles occurs three times. For a larger set of data, however, it would be necessary to keep a tally, by writing down each different value, marking each time it occurs and then counting the tallies for the distances in miles, as in Table 11.

A tally is one mark or a set of marks making up a record of occurrences. In tallying, every fifth mark is a line through the previous four. Thus, '7' is shown as 𝍸 ||. This enables counts to be quickly totalled in fives.

Table 11 Tallying occurrences of similar data

Value	Tally	Count
113	|	1
115	|	1
118	|	1
120	|	1
121	|	1
125	|||	3
131	|	1
		total **9**

This produces a type of average called the *mode* of the data set, but it is not always the most convenient average to use. Sometimes, no value occurs more than once, or sometimes there are two or more values that occur equally frequently.

Median

Another way of finding an average to represent a set of data is to arrange the values in order of size and then pick the middle value. This middle value is called the *median*. The median is fairly easy to find for a small data set. Arranging the nine distances (in miles) in order gives:

113 115 118 120 **121** 125 125 125 131

So the median (middle) value is 121 miles.

One advantage of using the median as the average value is that it is not affected very much by an exceptionally high or low value. For example, suppose you decided to drive from Bristol to Plymouth along the scenic route, and after getting lost once or twice near the coast, actually clocked up a distance of 300 miles for the journey! Including this distance in order in the list would give:

113 115 118 120 **121** **125** 125 125 131 300

As there are now ten values in the list, there are two middle values: 121 miles and 125 miles. The median is then defined as the value half-way between these two values. It can be found by adding the two middle values together and then dividing the answer by two.

So, the new median value is 123, which is very close to the earlier median value of 121 miles. The median has been affected only slightly by one unusually high value.

Mean

Most often, when people use the term 'average', they are actually referring to the *mean*. This is the value you get when you add all the values together and then divide your answer by the number of values in the set. The mean takes account of every item of data, and is often used in further statistical work.

For the nine distances in the table, the mean mileage is calculated like this:

Mean distance

$= (125 + 113 + 118 + 125 + 121 + 125 + 115 + 120 + 131) \div 9$ miles

$= 1093 \div 9$ miles

$= 121.4$ miles (to 1 d. p.)

Try working out the mean for the ten distance values including the scenic route.

You should find that the mean distance is now 139.3 miles, an increase of nearly 18 miles.

So, the mean *can* be affected by an extreme value. But extremes can also cancel each other out. To illustrate such a case, think how it would feel to

have your head in an oven and your feet in a freezer! Your mean temperature might appear comfortable, but it would not be a very useful representation of your general level of comfort!

So, looking back at Table 10, there are three possible 'average' values:

- the mode is 125 miles
- the median is 123 miles
- the mean is 121.4 miles.

As these values are different, it is important that you always state clearly which average you are using, and why. Since the mean, mode and median for a set of data are not necessarily the same, you also need to be wary of statements in the media that just talk about 'averages' without specifying which ones.

Activity 32 Averages

Using the distances in kilometres in Table 10, work out the mode, mean and median values.

(a) The mode is 201 km.

(b) The median is 195 km (easily seen when the list is given in ascending order: 182 185 190 193 **195** 201 201 201 210).

(c) The mean is 1759 ÷ 9 km = 195.33 km = 195 km to the nearest km.

Giving an average is a useful way of summarizing a set of data, but it is just as important to describe how the values are spread out around that average.

Remember the oven and freezer example.

One of the simplest ways of measuring the spread of a set of data is to find the difference between the highest and lowest values. This difference is called the *range*.

Activity 33 Range

Work out the range of the distances in Table 10 in both kilometres and miles.

(a) Range in kilometres = 210 – 182 km = 28 km.

(b) Range in miles = 131 – 113 km = 18 miles.

There are a number of ways of summarizing and representing a set of data to make it more understandable or more useful for a variety of purposes. This is the function of 'statistics', which is a complete field of study on its own. Its techniques are used in a wide range of disciplines, including the sciences, social sciences, and some of the arts.

If a more exact measure of the distance between Bristol and Plymouth were needed, then the measuring procedure and tools used would have to be different. For example, when a stretch of road is to be resurfaced, it is surveyed, using specialist tools such as a theodolite, measuring tapes and trundle wheels (see Figure 12). Sometimes, in remote areas, these measurements are calculated from aerial or satellite photographs that have been carefully calibrated from exact positional information, but even then no measurement can be 100 per cent exact.

3.4 Methods and tools

As mentioned in the last section, the methods and tools used depend on the exactness needed for a particular purpose and the particular quantity being measured (length, mass, capacity and so on). Although different tools are used for their different properties, it is possible to get an idea of the issues involved by considering the different ways of measuring length.

Direct measurement

This is where a scale such as a ruler or tape measure is positioned directly on to the object to be measured and the length read off. (This is similar to measuring a quantity of liquid by pouring it into a measuring jug and reading off the scale on the side.)

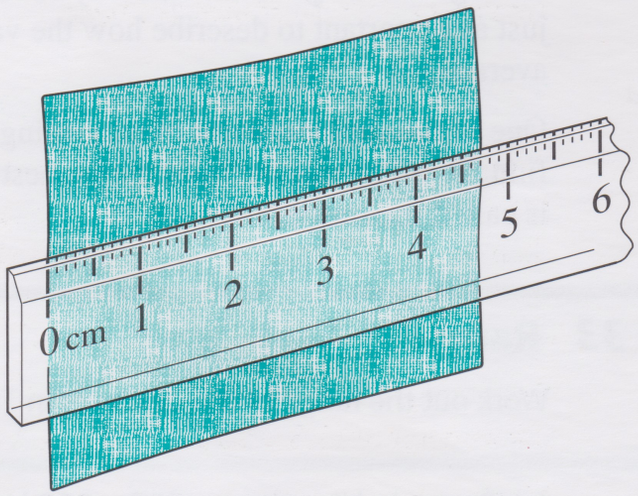


Figure 10 *Direct measurement*

Indirect measurement

Sometimes direct measurement cannot be used. For instance, if the object being measured is not straight (like a road on a map), an alternative method is to use an intermediate stage, with a strip of paper or piece of string, and then to transfer or compare the measure to a linear scale. (Remember the Pimm quotation in Chapter 1, Section 1.2.)

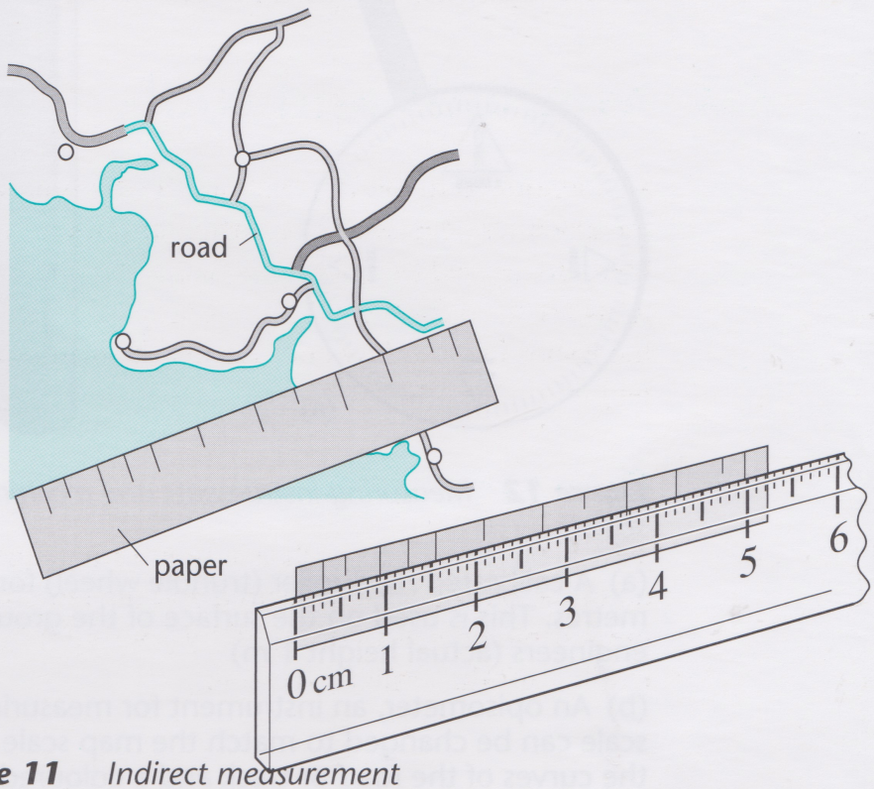


Figure 11 *Indirect measurement*

Tools, instruments and machines

Look up 'tool', 'instrument' and 'machine' in a good dictionary.

A third way is to use a tool, instrument or machine to convert movement (of a wheel, a screw or a spring, perhaps) to a scale or number, which is then read off. This is the approach used in measurers such as trundle wheels and odometers, which convert the distance travelled by a point on a circular wheel into a linear measure.

Small lengths such as the diameter of a nut are measured using a micrometer, which uses the principle of a screw.

Many measurements in the sciences use some type of instrument, from simple instruments such as a spring balance to complex ones such as electron microscopes. The end result, however, still depends in most cases on an operator's reading, either off a scale or a digital read-out.

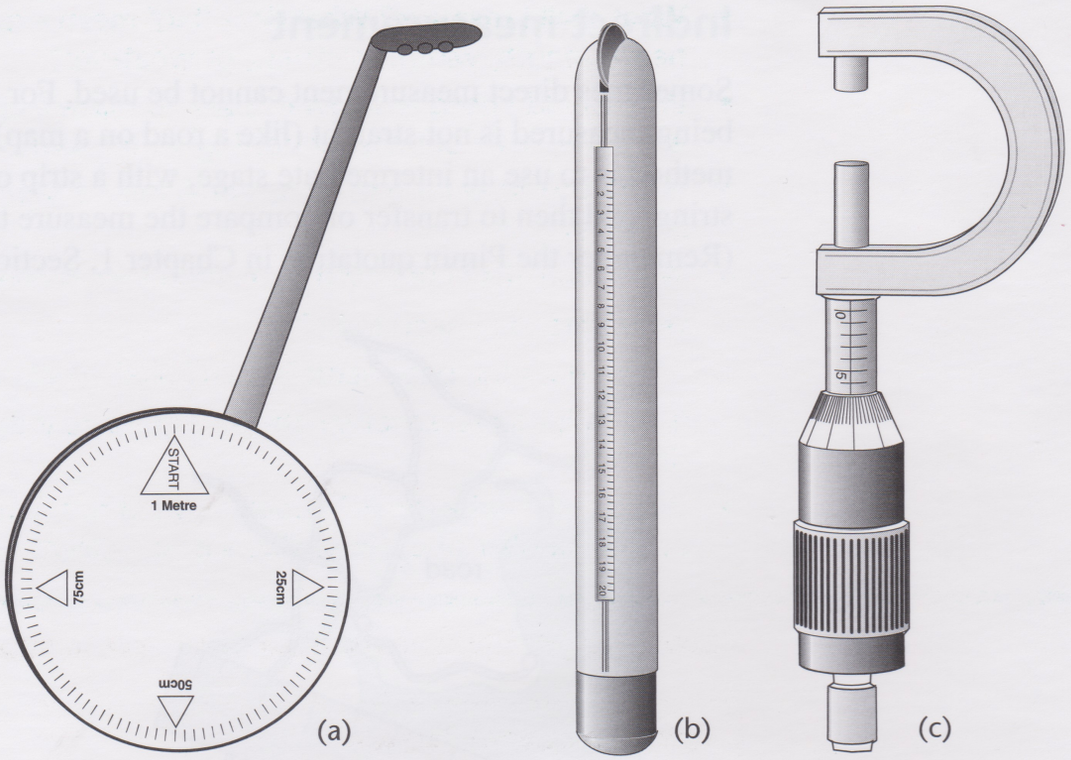


Figure 12 *Measuring instruments and machines (not drawn to the same scale!)*

(a) A calibrated road roller (trundle wheel) for measuring distances in metres. This is used on the surface of the ground itself, by surveyors or road engineers (actual height 1 m)

(b) An opisometer, an instrument for measuring distances on maps. The scale can be changed to match the map scale. The bevelled wheel follows the curves of the road or track and a coloured marker travels up the scale to show the distance represented (actual length about 15 cm)

(c) A micrometer, a precision engineering instrument for measuring to within fractions of a millimetre. Small objects are placed between the jaws to measure thickness or diameter: the screw thread allows tiny adjustments to show up clearly on the divisions around the collar (actual length about 15 cm)

Activity 34 Practical measurement

Think about the issues that have been covered so far in this module (perhaps look over your notes), and then answer the following question.

How big is this Study Book?

Doing is an important part of learning.

The purpose of this activity is to remind yourself of what it is like to make a measurement and to recall the thoughts you might have as you perform the task.

Write down your thoughts and any questions that arise.

Your thoughts to yourself should have included some of the following, but not necessarily in this order.

- What shall I measure? What does 'big' mean – number of pages, how heavy, length, width, thickness, or whatever?
- Why would I need to know its size? To make a cover, put in an envelope, work out cost of posting, or for some other purpose?
- Which tool shall I use to measure? A ruler, a tape measure, kitchen scales, or ...?
- What units shall I use? Inches, centimetres, millimetres, grams, or ...?
- How exact do I need to be?
- Where does the page actually start? Shall I include the cover?
- Is my solution reasonable? Should I measure it again? If so, how many times?
- What shall I write down? Should I round to the nearest whole number, or to a number of decimal places or significant figures?

These thoughts illustrate the important issues in measurement.

Measurement issues

- Purpose – why?
- Boundaries – exactly what?
- Units?
- Tools and their use – how?
- Quality of measurement – how should it be quoted?

Deciding on the boundaries and aligning the measuring scale are not always straightforward. Magnifying an example illustrates the problem (see Figure 13).

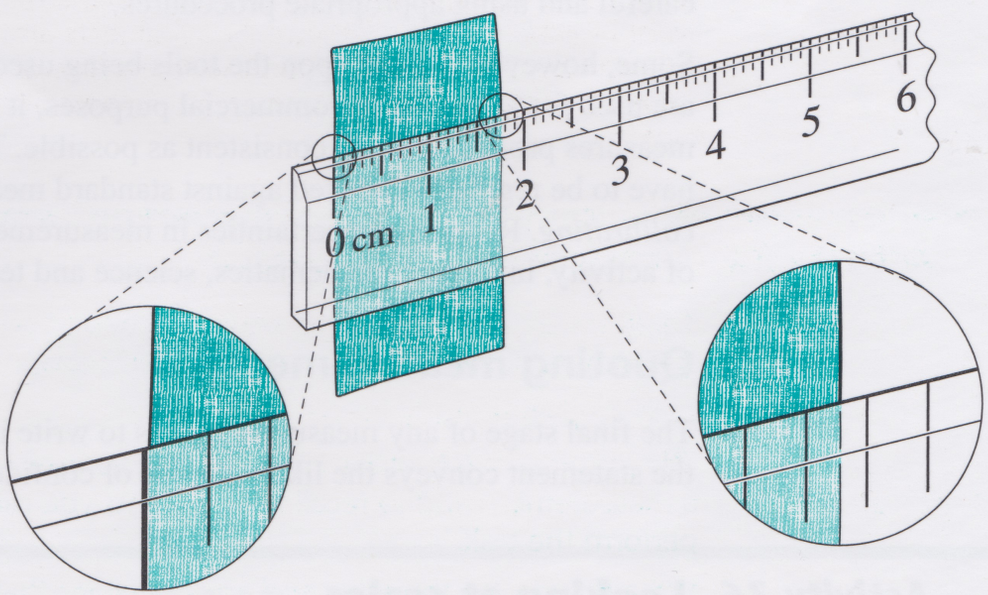


Figure 13 *A measuring task magnified*

Quality of measurements

Any quantity is in theory exact, but in reality any measurement is dependent upon both the tools used and how well the measuring procedures (such as setting the boundaries, or reading off scales) were applied. No physical measurement can ever be exact: upper and lower possible values may be known but there is always some doubt about what the exact measurement is. In scientific terms, this means that:

for any measurement there is a degree of uncertainty.

These uncertainties arise from the measuring tools themselves and the way that they are used. It is obviously important to reduce the effects of these uncertainties, and there are many ways this can be done.

Activity 35 Thinking about measuring

When you were carrying out Activity 34, what steps did you take to make sure that your measurements were as good as possible?

Some of the things you might have done.

- Use a metal ruler rather than a bent plastic one.
- Make sure that the zero mark lined up with an edge.
- Measure along an edge rather than across the middle.
- Measure the same dimension several times and take the mean.
- Zero the kitchen scales before using them.

These are all ways of reducing the uncertainties. Most are matters of being careful and using appropriate procedures.

Some, however, depend upon the tools being used. When measuring tools are used for scientific or commercial purposes, it is important that the measures produced are as consistent as possible. The tools used therefore have to be regularly checked against standard measures. This is called *calibrating*. Reducing uncertainties in measurements is a very important area of activity, involving mathematics, science and technology.

Quoting measurements

The final stage of any measuring task is to write it down in such a way that the statement conveys the likely degree of confidence that can be given to it.

Activity 36 Looking at scales

Look at Figure 14. How closely do you think you might be able to measure, using the top ruler shown?

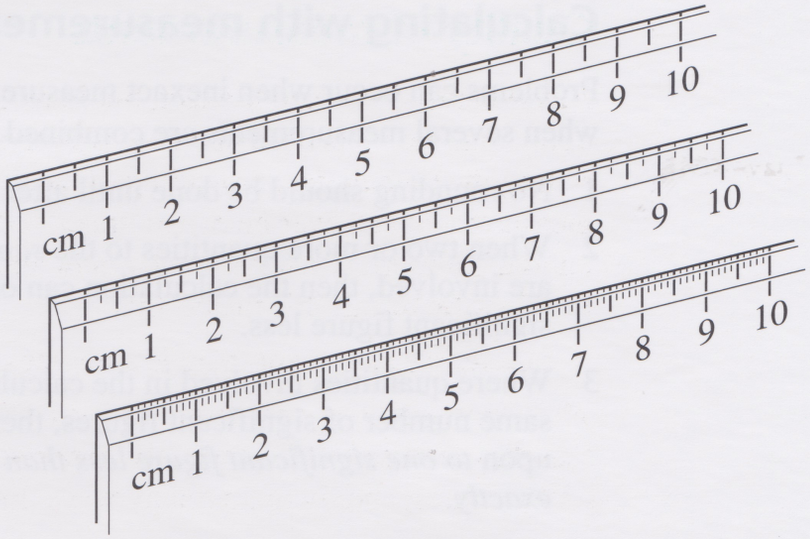


Figure 14 *Rulers*

The top sketch only shows half-cm divisions, so a measurement can be given to no more than the nearest half-cm.

In the sciences, there are conventions for expressing measurements either with the uncertainty stated, or in such a way that it is implicit in the number of significant figures quoted. It is good practice to quote this degree of exactness, so a measurement from the top ruler might be written as, for example:

1.5 cm to the nearest half-cm

Using the bottom ruler, it would be possible to measure to the nearest one-tenth (0.1) of a cm, so again that should be quoted. However, a measurement written to 1 d. p. (1.7 cm, for instance) already implies that the measurement is to the nearest tenth.

This convention is used in the tachograph regulations shown in Section 3.2.

There are other ways of writing measures to indicate exactness: ±2 minutes per day, for example. A measure written this way is termed a *tolerance figure.*

Activity 37 Approximations and uncertainties

pages 346 to 352

Section 6 of the Maths Help section of the SGSG is about approximations and uncertainties and includes guidance on decimal places and significant figures. Work through that section now.

However much care has been taken to use calibrated tools and apply measuring procedures carefully, any measure is inherently inexact to some extent. This is why it is so important to always quote measurements in such a way as to indicate the level of confidence that can be given to them.

Calculating with measurements

Problems can occur when inexact measurements are used in a calculation or when several measurements are combined. Several precautions can be taken.

1 No rounding should be done until after the calculation.

2 When two or more quantities to the *same* number of significant figures are involved, then the calculation can only be relied upon to one significant figure less.

3 Where quantities involved in the calculation are not all known to the same number of significant figures, then the result can only be relied upon *to one significant figure less than the quantity that is known least exactly*.

Merely calculating the answer the arithmetic produces is not enough: it has to be interpreted sensibly in relation to both the use to which the solution is to be put and the reliability of the original measurements.

Activity 38 Reflection

Study skills

Look through your notes and activity results, and make sure they are organized in a way that will make sense to you when you look back. Skim through the chapter text to make sure that your notes are an adequate record, and highlight the important points. Think about what you have learned in the first three chapters.

What are the key issues in making and using measurements? List the factors, with a brief explanation of each. First, try to do this without reference to your notes, and then use your notes to check what you have covered.

Think about what you have learned about studying and learning. Look at your study plan for the chapter. How did it work out in practice? Make some notes to yourself in your Study Diary about what suits you best: for example, when you find you can concentrate most easily, roughly how long to allow yourself to understand a page of text, and so on.

Finally, look at the learning outcomes that follow. How close are they to your own list of key issues in making and using measurements? Whenever objectives or outcomes are presented in course material in this way, be sure to use them.

Learning Outcomes

You should now understand that:

- a graph or chart can condense a great deal of information into a small space, and that skill and care are needed in interpreting them
- there are different ways of summarizing data, such as range, mean, mode and median
- no measure can be exact: there are always going to be uncertainties, depending on the tools and measurement procedures used
- the level of confidence in a measurement is reflected by the way it is quoted: this may be shown explicitly, by giving a range or tolerance value, or implicitly, by the number of significant figures retained
- terms such as 'accuracy' and 'precision' have particular meanings in the sciences.

You should now be more able to:

- plan your studies to make effective use of time
- interpret graphical representations, and read off information from graphs, maps, tables and charts
- calculate the range, mean, median and mode of a set of data
- perform conversion calculations, showing clearly the steps in your working
- use your Study Folder to keep a personal dictionary of technical terms and symbols; make notes summarizing a section of work; and reflect on your own learning.

CHAPTER 4 IN THE FACTORY

It's all chocolate! Every drop of that river is hot melted chocolate of the finest quality. The very finest quality. There's enough chocolate in there to fill every bathtub in the entire country! And all the swimming pools as well! Isn't it terrific?

Roald Dahl (1964) *Charlie and the Chocolate Factory*

4.1 Introduction

Remember to plan your studies before starting work. Skim through this chapter and write your work plan.

This chapter is not about 'doing' measuring as such, but about how measures are used and represented statistically. Although the example chosen comes from a single industry, that of chocolate manufacturing, the ideas are common to any area where items are sold as a specified quantity or size. The chapter will also help you in:

- developing strategies for making sense of technical phrases and formulas
- practising the handling of data
- following calculations.

When you go shopping, how carefully do you look at the labels on the items you buy? More often than not, your time is likely to be taken up with trying to find the specific item or brand you want.

Activity 39 Just looking

Find a bar of chocolate and inspect the labelling (see the example in Figure 15). Do you know what all the symbols stand for? Do you know why all the information is on the packaging? Write down the information given on the wrapper, and next to each piece of information, write down what you think it means.

Nutrition Information		Per 100g
Energy	kj	2195
	kcal	525
Protein	g	7.8
Carbohydrate	g	56.8
Fat	g	29.4

Ingredients: milk, sugar, cocoa mass, cocoa butter, vegetable fat, emulsifier: 422, flavourings.

Milk solids 20% minimum, cocoa solids 20% minimum.

5 000201 477965 >

e250g

BEST BEFORE

14 APRIL 97 D3

STORE IN A COOL DRY PLACE

Figure 15 · *A chocolate bar wrapper*

You may have written down something about:

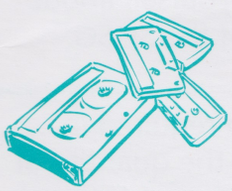
- the fat content of the bar
- the number of calories it contains
- who makes the particular bar of chocolate
- the quantity
- the best-before date
- the black-and-white striped bar code.

4.2 Short measures

When you buy a bar of chocolate, do you really know what you are buying? You can see what the bar contains by looking at the information on the wrapper. But how heavy should it be? Do similar bars of the same size contain exactly the same quantity of chocolate? This chapter will guide you through some of the legislation that applies to that measure of quantity.

Activity 40 Mr Periwinkle's complaint

Study skills



The next activity in this chapter is to listen to a piece of drama on Side 2, Track 1 of the audio-cassette.

How are you going to listen to it? Recall your experience of audio drama from Chapter 3.

There may be a number of new phrases and words that you have not met before and it may raise questions in your mind. How are you going to remember these?

The audio-cassette section itself ends with a question. The majority of this chapter is about solving this particular problem and it will lead you through a number of stages to a solution, explaining all the technical terms and the new ideas. Listen to the audio-cassette section now.

You may have written down words such as:

- calibrate
- nominal quantity
- **e** mark
- sampling
- trading standards.

Richard mentioned that his job used to be simpler when the legislation was based on minimum weight. By the end of this chapter you will have decided whether Richard's job used to be simpler than it is now, and whether Mr Periwinkle had a point.

You should have also noticed that the word 'weight' was being used when, scientifically speaking, it should have been mass. Look back to the box at the end of Section 2.3 of this Study Book, to remind yourself that there is a difference between the everyday use of the word 'weight' and the scientific one.

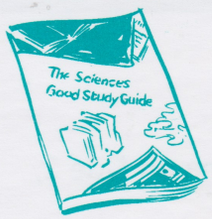
Mr Periwinkle's main complaint was that his bar did not contain the quantity of chocolate stated on the packet. There is a document that confectionery manufacturers have to follow when they are making bars of chocolate. It is titled *A Code of Practical Guidance for Packers and Importers*. It contains the Weights and Measures Act 1979, and is generally referred to as The Packers' Guide (Department of Trade and Industry, 1979).

Activity 41 Reading text: guidance for packers

Study skills

Your next activity is to read through an extract from this document, and as you are reading note down or highlight the points that you think might be important for solving the problem with the bar of chocolate.

This extract is designed to show you the kinds of documentation that might be encountered in an industrial setting, so do not worry about trying to understand all the terms. These will be explained as the chapter progresses.



pages 36 and 37

Which reading strategy are you going to use? To remind yourself about scanning and skimming, look again at pages 36 and 37 of the SGSG.

> Prior to 1 January 1980, the law of the United Kingdom required in general that a container marked with a statement as to the quantity of goods it contains must contain at least that quantity. This requirement applied at all stages in the supply of the product, right up to the point of retail sale. This regime is referred to in this Code as 'the minimum system'. The legislation was however effectively modified by a publication which was issued in 1969 and entitled *A Guide to Good Practice in Weights and Measures in the Factory*. It gave guidance to packers and constituted an agreement between the Confederation of British Industry and the then Institute of Weights and Measures Administration as to what would be regarded by enforcement officers (Inspectors) as acceptable degrees of underfill in prepacked goods ('inconsiderable deficiencies').
>
> Department of Trade and Industry (1979)

A great deal of official documentation is very wordy and uses complex sentence structures. In this case, scanning is the best strategy, and you should have been able to extract or highlight the following points:

- Prior to 1 January 1980
- a container marked
- as to the quantity
- must contain at least that quantity

- applied at all stages
- up to the point of retail sale
- minimum system
- modified
- 1969
- *A Guide to Good Practice*
- acceptable degrees of underfill.

Activity 42 More guidance

Read the following extract from Cadbury's own version of The Packers' Guide and make notes on the important points. Which is the easier extract to understand? Does the second extract give you any extra information?

> Until 1980 the UK operated a minimum weight system, i.e. the weight declared indicated that the package contained at least the quantity specified. *A Guide to Good Practice* was issued in 1969 which defined how the law should be interpreted and what would be regarded as an acceptable level of underfill. This can be basically summarized in two requirements.
>
> 1 No pack should contain less than 96% of the weight declared.
>
> 2 No more than 2.5% of the packs should contain less than the weight declared.
>
> Cadbury (1995)

You may have noted that the second extract is written in a more understandable form, but it also gives you extra information. For example, it states two requirements that allow you to calculate whether a chocolate bar is acceptable under the modified minimum-weight system.

If a bar of chocolate was labelled as 50 g then, under the old minimum-weight system, this particular bar would have been within the acceptable limits if it actually weighed at least 96 per cent of this declared quantity (point 1 above).

96% of 50g can be calculated as:

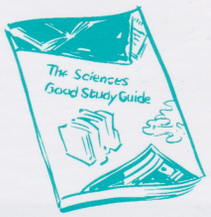
$$\frac{96}{100} \times 50 = 48 \text{ g}$$

or, written another way:

$$0.96 \times 50 = 48 \text{ g}$$

So, if a bar of chocolate was labelled as 50 g and the actual quantity was at least 48 g, then it was within the legal limits.

Activity 43 Using percentages



pages 339 to 345

If you are not confident in handling percentages, work through Section 5 of Maths Help in the SGSG, beginning on page 339.

What about the following individual bars of chocolate? What would be the least quantity they could contain and still be legal under the minimum-weight system?

(a) 100 g bar

(b) 40 g bar

(c) 1.25 kg bar

(a) $\frac{96}{100} \times 100\text{ g} = 96\text{ g}$ (or $0.96 \times 100\text{ g} = 96\text{ g}$)

(b) $0.96 \times 40\text{ g} = 38.4\text{ g}$

(c) $0.96 \times 1.25\text{ kg} = 120\text{ kg}$

But there was a second point in the extract above.

- No more than 2.5% of the packs should contain less than the weight declared.

So, if 100 50-gram bars of chocolate were weighed, then only 2.5% of them (that is, 2.5 in every 100) could weigh under 50 g.

In this case, the precise number of 2.5 bars of chocolate seems a little absurd. Do you think the number 2.5 should be rounded up or down?

It could be the case that the supplier would like to round the number up to 3, whereas the purchaser would like it rounded down to 2! However, in practice, among the many thousands of bars being produced, the 2.5% makes sense. You might prefer to think of it as 5 in every 200.

This legislation meant that the manufacturer had to produce bars of chocolate that were nearly always overweight in order to satisfy the minimum-weight legislation. However, they needed to keep the size of the bars as close to the minimum weight as possible in order to reduce production costs.

Activity 44 Skim reading: getting to grips with the three rules

Study skills

The following extract is also from Cadbury's documentation. Skim through it, and then read it again, noting down any words or phrases you do not understand.

Now the European Union.

In 1980, as part of the harmonization within the EEC, the law was changed so that an 'average' system came into force. Under this, the weight declared is an average for the product, but there are other specific laid-down requirements to restrict the amount of variability in a pack. A packer can ensure that all requirements of the legislation are met if he follows the 'Three rules for packers'.

Rule 1. The actual contents of the packages shall not be less, on average, than the nominal quantity.

Rule 2. Not more than 2.5% of the packages may be non-standard, i.e. have negative errors larger than the TNE (tolerable negative error) specified for the nominal quantity.

Rule 3. No package may be inadequate, i.e. have a negative error larger than twice the specified TNE.

Cadbury (1995)

page 37

The skill of skimming has been mentioned earlier and it is referred to in the SGSG (page 37). Skimming gives a feel for what a passage is about, in this case a guide to the legal requirements for packaging that came into force in 1980.

Writing down the phrases and words that are new or not understood is a good strategy for starting to get to grips with difficult text. The following are technical phrases that will be explained later in the chapter:

- nominal quantity
- TNE – or 'tolerable negative error'.

'Non-standard' and 'inadequate' are also being used as technical terms.

These technical terms will stand out as you quickly read the text. It is unlikely that you'll have to remember the particular terms after you've finished reading the module. You will know by now that the motive here is to highlight key measurement issues, rather than examine the fine detail of particular examples. But to make sense of this chapter you'll need some sense of what these terms mean. Write them down in your personal dictionary, along with any other terms you did not understand, and add further detail to these new entries as convenient.

You should have understood 'average' from the last chapter, and asked yourself 'Which one?' The answer is the mean – Cadbury uses the everyday word instead of the technical term.

If you look back at your answer to Activity 39, you may have noted that there is a letter **e** on the label, next to the weight. This is sometimes referred to as the **e** mark but is correctly known as the *nominal quantity mark* and was referred to in the audio-cassette extract.

Make a note of the definition.

It is not only chocolate that carries this mark: look for it on other products.

The **e** mark signifies that goods have been packed in accordance with the average-weight legislation, and consequently that the goods are allowed free (unrestricted) passage throughout the European Union. If you refer back to Figure 15, you'll notice the **e** mark next to '250 g', which is the nominal quantity for this product.

Activity 45 Minimum and average

Now try to summarize the minimum-weight and the average-weight requirements. What is the difference between them?

Minimum weight

Any single package had to contain at least 96 per cent of the minimum quantity declared on the package. Also, no more than 2.5 per cent of any batch could contain below the declared quantity.

Average weight

The actual contents are required to be not less on average than the stated nominal quantity. Only 2.5 per cent of a batch may be 'non-standard', and none must be 'inadequate'.

Since 1980, it is has not been possible for the consumer to decide whether a chocolate bar meets legal requirements without knowing what constitutes an 'inadequate' package.

4.3 Ranges and averages

The following activities will take you through the 'Three rules for packers', one rule at a time, explaining the calculations involved. You will be asked to do some of the calculations for yourself.

Rule 1 talks about average (mean) quantities of packages.

Would it be sufficient to weigh 3, 10, 50, 100 or 1000 chocolate bars? What kind of scales should you use? How closely must the measuring be done? How many bars of chocolate do you think should be weighed to find the average (mean) quantity?

If you think of a small (50 g) bar of chocolate, there would be little point in weighing it on a set of bathroom scales, because they are not good enough for this purpose. You might have some kitchen scales that have a scale marked in grams, but as it said on the audio-cassette, you do not know how well they measure, because, unlike the Trade Standards Office scales, they are not regularly calibrated (that is, checked against a standard).

To ensure that their products remain within the average weight legislation, Cadbury samples its production runs.

The required sample size is dependent on the production rate per hour and is shown in Table 12.

Where production is less than 100 per hour, all packages should be included.

Table 12 Cadbury's required sample sizes

Production rate	Sample size
100–500	50
501–3200	80
3201 and over	125

Cadbury (1995)

One of the authors weighed 100 bars of chocolate with a nominal quantity of 64.5 g on a calibrated electronic balance, giving the results in grams, correct to 2 decimal places.

The weights are recorded in Table 13.

Remember that these values represent the mass of the bars (see Section 2.3). The units have to be stated: this is written either in brackets (g) or, more correctly, as /g, as in these headings.

Table 13 Results of sample weighings

Bar	Mass without wrapper/g	Bar	Mass without wrapper/g	Bar	Mass without wrapper/g	Bar	Mass without wrapper/g	Bar	Mass without wrapper/g
1	64.51	21	63.70	41	65.49	61	62.87	81	65.49
2	65.02	22	64.62	42	66.21	62	65.41	82	64.69
3	63.11	23	64.98	43	67.04	63	65.53	83	62.85
4	62.58	24	65.57	44	65.99	64	66.75	84	65.81
5	62.58	25	67.73	45	65.99	65	65.29	85	63.97
6	62.88	26	68.81	46	66.68	66	64.85	86	63.58
7	66.29	27	66.76	47	67.10	67	66.71	87	65.37
8	64.56	28	63.76	48	67.16	68	65.98	88	64.06
9	62.87	29	65.36	49	67.86	69	66.02	89	63.46
10	64.03	30	65.54	50	65.92	70	65.80	90	64.42
11	63.58	31	66.79	51	65.45	71	65.68	91	66.55
12	63.78	32	67.13	52	66.12	72	66.72	92	65.74
13	65.61	33	66.19	53	64.93	73	65.00	93	64.58
14	64.25	34	67.68	54	66.73	74	64.88	94	64.52
15	62.10	35	66.50	55	64.92	75	64.44	95	66.34
16	63.72	36	65.76	56	64.32	76	62.34	96	63.59
17	63.72	37	65.84	57	64.29	77	65.82	97	63.78
18	65.94	38	64.39	58	67.64	78	63.49	98	65.15
19	64.85	39	65.54	59	67.38	79	63.47	99	64.20
20	62.81	40	67.14	60	65.01	80	65.14	100	64.33

Activity 46 Handling data: 100 bars

Study skills

Calculate the range and mean of the set of 100 results. Then decide whether the sample meets Rule 1 of the average-weight legislation – that is:

> *the average (mean) quantity shall not be less than the nominal quantity of 64.5 g*

Spending a lot of time on a question like this may seem a rather inefficient use of your study time, but if you are unused to dealing with a lot of figures, you will need to develop your own strategies for avoiding careless errors.

Dealing with this amount of data can be quite a daunting task. Before you begin, think carefully about how you are going to carry out the activity. How are you going to make sure that you do not include one weighing twice, or miss one out? What are you going to do if your answer is not the same as the one below?

Hint: You could break the 100 sample into groups of 10. Find the total for each group of 10 and then add these together at the end.

It can be very disheartening when you spend a long time on a calculation only to get a different result from the one in the book. But of course, in the real world there is no book solution to compare with yours, so checking procedures is an important skill. You need some strategies for checking your own calculations.

One possible strategy is to add once from top to bottom, and then from bottom to top. Both ways should produce the same result.

To avoid repetition, it may be helpful if you cross out each figure once you have entered it into your calculator.

When you do any calculation, especially on a calculator, always remember to estimate what your answer should come to: this should prevent any gross mistake.

It can be difficult to imagine what 6.71 g of chocolate feels like. It might help if you could imagine an object of a similar weight: a 20p coin, for example, weighs approximately 5 g.

For example, if your working gave the mean as 6.515 g or 651.5 g, you should realize that these answers are unreasonable.

The results are:

range = 68.81 – 62.10 g = 6.71 g

mean = 65.15 g, correct to 2 decimal places.

The set of chocolate bars weighed satisfy Rule 1 of The Packers' Guide, because the average weight, 65.15 g, is not less than the nominal quantity of 64.5 g.

'Tolerable negative error' is a term used by the EU, and not one you need to know for MST studies. The following section is designed to give you experience of working through technical explanations that use formulas and equations in both word and symbol form. Symbols are frequently used in MST subjects as a form of shorthand.

Activity 47 Formulas

pages 365 to 370

Work through Section 9 'Formulas and algebra' of the Maths Help section of the SGSG, beginning on page 365.

Rule 2 is about non-standard packages and the tolerable negative error (TNE). The TNEs are given in another table in The Packers' Guide, but just part of it is reproduced as Table 14.

TNEs shown as percentages should be rounded up to the nearest 1/10 g or ml above, when calculated in units of weight or volume.

Table 14 Tolerable negative error

Nominal quantity (Q_n)/ g or ml	Tolerable negative error (TNE)/ g or ml
50 to 100	4.5

Notice that in the table the nominal quantity has been given the symbol Q_n (Q for quantity with the subscript 'n' for nominal). When you see the symbol Q_n, remember to say 'nominal quantity' in your head.

The bar of chocolate that was weighed had a Q_n (nominal quantity) of 64.5 g. Reading off from the table, the TNE (tolerable negative error) for a Q_n of 64.5g, is 4.5 g.

A non-standard bar of chocolate is one that contains less than:

the nominal quantity (Q_n) minus the tolerable negative error (TNE)

In this case,

Q_n – TNE = 64.5 g – 4.5 g = 60 g

Look back at the set of data linked with Activity 43 (Table 13).

- Do any of the chocolate bars break Rule 2 of The Packers' Guide?

○ No, there are no bars that have a quantity less than 60 g, so the sample does not contain any non-standard bars.

Therefore, the bars weighed fully satisfy Rule 2 of The Packers' Guide.

Rule 3 mentions 'inadequate' packages. An 'inadequate package' is one that contains less than (the nominal quantity *minus* twice the TNE). Translating this statement to symbols, an inadequate package is one containing a quantity less than:

$Q_n - (2 \times \text{TNE})$

In this case:

$Q_n - (2 \times \text{TNE}) = 64.5\text{ g} - (2 \times 4.5\text{ g}) = 55.5\text{ g}$

A package would therefore be declared inadequate if the quantity were less than 55.5 g.

- Look back at the table of data. Are there any bars with a quantity less than 55.5 g?

○ No, which means that Rule 3 of The Packers' Guide is also satisfied.

4.4 Understanding and using

At the end of the audio-cassette section, Mr Periwinkle complained that one of his 'special offer 10% free' bars of chocolate contained 213 g and was under weight.

> *It's obvious, isn't it? This bar, original nominal quantity: 210 grams. 10% of that is 21 grams. 210 plus 21 equals 231. So the special offer nominal quantity is 231 grams!*

Activity 48 Under weight or not?

Was Mr Periwinkle's complaint justified?

Remember to show your working clearly.

To calculate the values for non-standard and inadequate bars of chocolate when the nominal quantity is 210 g, you need to know the tolerable negative error for a bar of chocolate weighing 210 g.

The TNE needed has been extracted from The Packers' Guide and is shown in Table 15.

Table 15 TNE for Mr Periwinkle's problem

Nominal quantity (Q_n)/ g or ml	Tolerable negative error (TNE)/ g or ml
200 to 300	9

A non-standard bar would be less than:

$Q_n - \text{TNE} = 231\text{ g} - 9\text{ g} = 222\text{ g}$

So, Mr Periwinkle's bar weighing 213 g was certainly a non-standard bar. But the inspectorate would need to establish that more than 2.5 per cent of similar bars were also non-standard before any offence could be said to have been committed.

But to be an illegal, inadequate package it would need to be *less* than $Q_n - (2 \times \text{TNE})$.

$Q_n - (2 \times \text{TNE}) = 231\text{ g} - 18\text{ g} = 213\text{ g}$

So the bar *was* legal, just.

So the answer to Mr Periwinkle would be: 'Yes the bar is under weight, but not illegally so.'

To return to the audio-cassette, do you think that Richard's job was simpler in the days of minimum weight than it is now?

It is certainly easier to check whether a bar of chocolate is below a minimum weight, rather than trying to calculate whether a particular bar is inadequate or establish that a batch contains too many non-standard bars. From a consumer's point of view, the minimum-weight legislation was far easier to understand, and for the inspectorate, easier to explain.

Activity 49 Reflecting

Study skills

What have you learned or revised, and practised, in working through this chapter? Think about the measurement issues covered, study skills and maths confidence.

What aspects were particularly interesting to you, and which parts did you find most difficult?

How did you overcome any difficulties? For example, did you talk to someone? Take a break? Work through it again, more slowly?

Think about the answers to these questions and make some notes for yourself. These will prove helpful when you meet difficulties in future studies.

Learning Outcomes

You should now understand that:

- measuring instruments and tools need to be calibrated regularly for reliable results
- mathematical solutions need to be interpreted for use in the 'real' world
- symbols are used as shorthand and must be 'read' in full to make sense.

You should now be more able to:

- plan your own work independently
- use skimming and scanning and so on
- calculate, using percentages
- cope with large data sets
- use simple formulas expressed in symbols.

CHAPTER 5 IN THE NATURAL WORLD

'And the only reason for being a bee that I know of is making honey.'

And then he got up and said:

'And the only reason for making honey is so I can eat it.'

A. A. Milne (1926) *Winnie the Pooh*

5.1 Introduction

This chapter is about just a few of the many situations where measurements need to be taken and used, both by beekeepers and scientists. Unlike previous chapters, in which the measurements required in cooking, making journeys and manufacturing chocolate, for example, were decided by people, the need for measurement here is dictated by the natural world: bees and flowers. There are also a couple of interludes, associated with bees, which provide contexts for an examination of large and small numbers and SI units.

Beekeeping is probably a new activity to you and will help develop further your strategies for dealing with unfamiliar topics. However, you will gain more experience on the measuring issues of:

- purpose
- boundaries
- units
- methods, tools and use.

So, you will be able to apply the knowledge and understanding you have built up over previous chapters.

Activity 50 Looking ahead

Study skills

The measurement issues are not specifically referred to in the text of this chapter. Towards the beginning of the chapter they are flagged up in marginal notes, but later you are expected to flag them up for yourself. (It's a good idea to use the margin of this booklet for your written notes.)

Look now at Activity 62 at the end of this chapter, and think about how you can prepare for this as you work through the text.

5.2 Beespace

Bees build nests of wax combs in which to lay eggs and store the food they process from nectar – honey (see Figure 16). Although bees have been kept for their honey-making ability for many thousands of years, it is only since 1851 that beekeeping has been a commercially viable proposition. Before that time, 'domestic' bees were kept either in boxes or in straw skeps, and the only ways to harvest the honey were either to kill all the bees in a hive or to drive them away from it.

A skep is a beehive made from straw, looking something like an upturned basket.

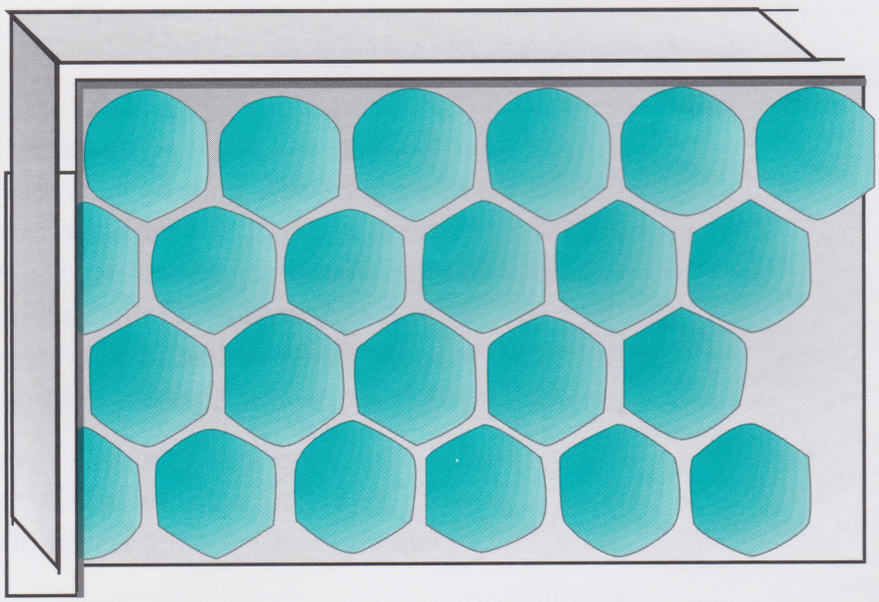


Figure 16 *Honey comb*

To maintain their nest, bees need to be able to move around inside it. In 1851, the Reverend L. L. Langstroth noticed that there was a *consistent space* between the wax combs that bees build in a natural nest. This discovery enabled him to design a hive with movable frames, spaced according to this constant 'beespace'. The frames could be removed to harvest the honey without disturbing the bees.

Activity 51 Making sense

You do not need to know the technical beekeeping words, but in case you are interested, 'propolis' is a sticky substance that bees obtain from plants and use as a glue for sealing cells in the comb, and 'brace comb' is extra comb (basically wax).

What strategies are you going to use to read the following technical description of beespace?

> Beespace is the space that bees require as a corridor. It is defined as being from 1/4 to 3/8 inches and in normal practice is usually 5/16 inches. If the space between two parts of the hive is less than 1/4 inch, the bees will fill it with propolis; if it is more than 3/8 inch they will build burr or brace comb.
>
> Adapted from Morse and Hooper (1985) *The Illustrated Encyclopaedia of Beekeeping*

Write down your immediate thoughts. For example, how do you react to fractions of an inch?

Try to get a picture in your mind of what 'beespace' might look like.

Did you notice that it is the width of a 'space' that is being measured here? (Accurate measuring of spaces is often critically important in the engineering world.)

Purpose

Did you wonder how bees know when the 'beespace' is outside the dimensions given? (The answer to the question 'How do bees measure?', if there is one, is beyond the scope of this chapter!)

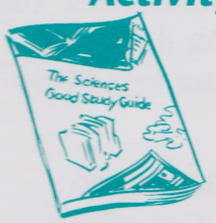
Units

You may have been struck by the use of fractions: 'can't do them' is a common response. You should have been able to visualize a quarter of an inch, or at least had some idea from the conversion work on inches in Chapter 2 of this Study Book.

Trying to picture a bee corridor can be difficult, but you may have visualized something like Figure 17.

Figure 17 *Bees in a corridor*

Activity 52 Fractions



pages 317 to 329

You may find it helpful at this stage to skim through Section 3 of Maths Help in the SGSG, beginning on page 317. A useful approach would be to tackle one or more of the maths activities (numbers 10 to 12, for instance). If you have any problem, you'll need to work through the entire section systematically.

Figure 18 shows a single wooden frame. The beekeeper fills this frame with a sheet of wax foundation, so that the bees can build up their comb to store the honey. Figure 19 shows a box called a 'super' where these frames (usually 11) are hung parallel to each other from ledges.

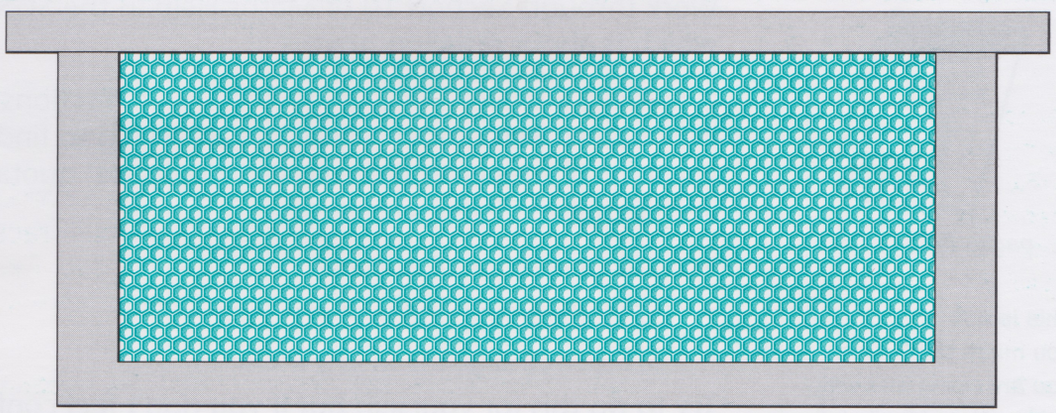


Figure 18 *Honey frame*

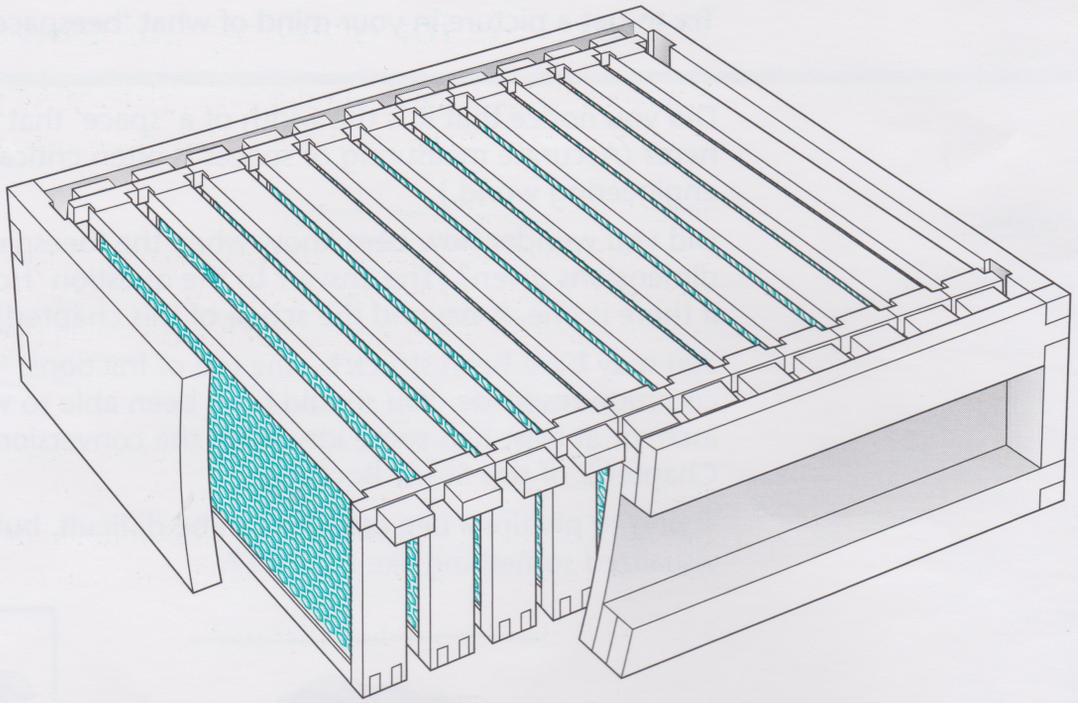


Figure 19 *Frames in a hive (adapted from Evans, 1989)*

Beekeepers in the UK and USA use imperial measurements of inches and fractions of an inch for the various dimensions of the hive. It can be difficult to imagine fractions of an inch, and with the scientific world standardizing to metric units it is better to convert these measurements into millimetres. You will recall that in Chapter 2 a calculation method was used for the conversion of inches to centimetres, with the conversion factor being 2.54 cm/in (that is, 1 inch = 2.54 cm or 1 inch = 25.4 mm).

The same method could be used here, but when there are a number of conversions to do, it is sometimes easier to read them off a graph which relates (maps) one set of measurements to the other. This will also avoid the need to covert the fractions of an inch to decimals.

Activity 53 Constructing a conversion graph

pages 376 to 383

This is not 'cheating'! But you must think about what you are doing and why, rather than blindly following the instructions.

Work through Section 10 of Maths Help in the SGSG, pages 376 to 383, which is about drawing graphs.

Construct a straight-line graph to convert fractions of an inch to millimetres. Remember, what you are trying to find out is what the fractions of measures given in the 'beespace' quotation are equivalent to in millimetres. These were:

- 1/4 (a quarter of an) inch
- 5/16 (five-sixteenths of an) inch
- 3/8 (three-eighths of an) inch.

Try to do this for yourself, but if you don't feel confident, follow the step-by-step instructions given below.

Instructions for drawing the conversion chart

You need a sharp pencil, a ruler and a piece of A4 paper (squared paper or graph paper would be easiest, but plain paper will do).

Draw and label the axes

Draw two lines, one parallel and close to the left side of the paper, and one parallel and close to the bottom edge, so that they cross near the left-hand bottom corner. Label the left-hand axis 'Millimetres' and the bottom axis 'Inches'.

Work out the scales for each axis

The measurements in inches that need to be converted range from 0 to 1/2 inch (16/32 inch), so there need to be 16 equally spaced divisions along the horizontal axis (the known or fixed variable). Half an inch is 12.7 mm, so the vertical axis needs to go from 0 to 13 mm, that is, 13 equally spaced divisions.

The result should look like Figure 20.

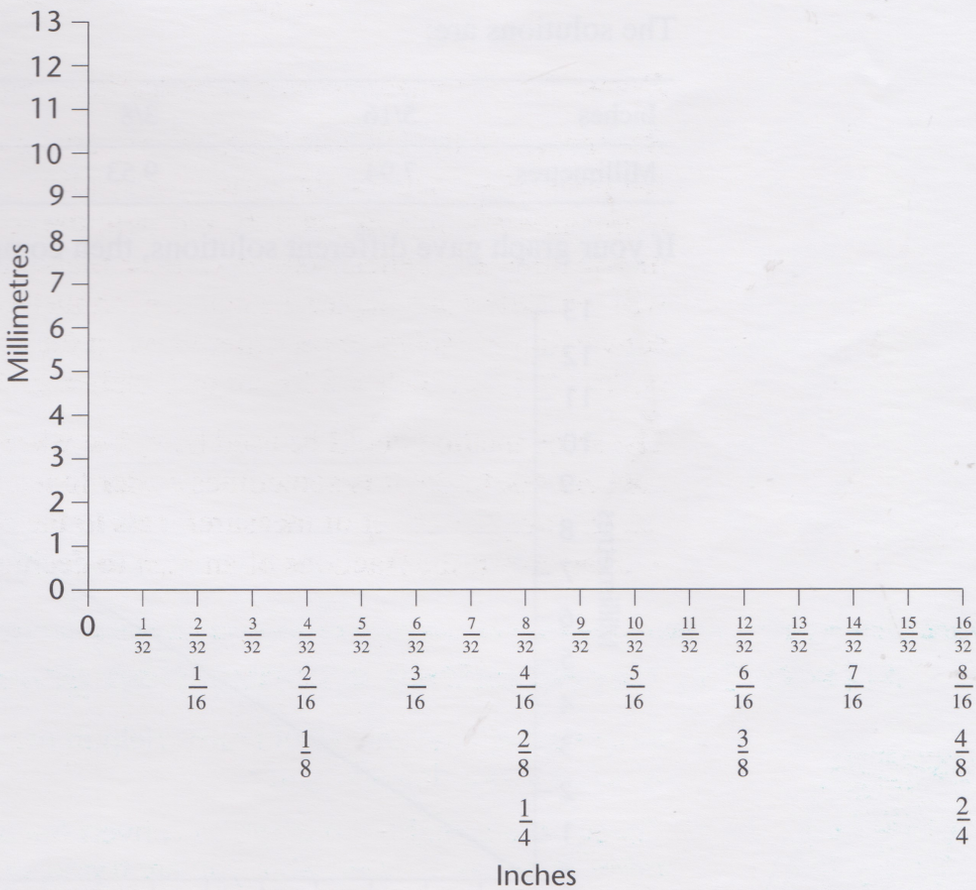


Figure 20 *Conversion graph axes*

Now you need to plot the known points. Strictly, only two are needed, but it is good practice to plot a third as a check.

Since you know that 1 inch = 25.4 mm, you can work out what a quarter-inch and a half-inch would be in millimetres. Another known point is (0, 0) since 0 inches must be equal to 0 mm. A simple and clear way to show these results is in the form of a table, such as Table 16.

Table 16 Conversion points for a graph

Inches	0	1/4	1/2
Millimetres	0	6.35	12.7

Plot the known points and draw the conversion line

The first point to plot is (0, 0): that is, where the axes cross in this case. Then plot (1/2, 12.7) by going along the horizontal axis to the 1/2-inch division line and then vertically up until level with 12.7 on the vertical axis.

Using a ruler, draw the straight line that joins these two points. This line should go through the point (1/4, 6.35).

Read off the conversions needed

Using the graph you have just drawn, read off the values in millimetres that are equivalent to 5/16 in and 3/8 inches.

The solutions are:

Inches	5/16	3/8
Millimetres	7.94	9.53

If your graph gave different solutions, then compare it with Figure 21.

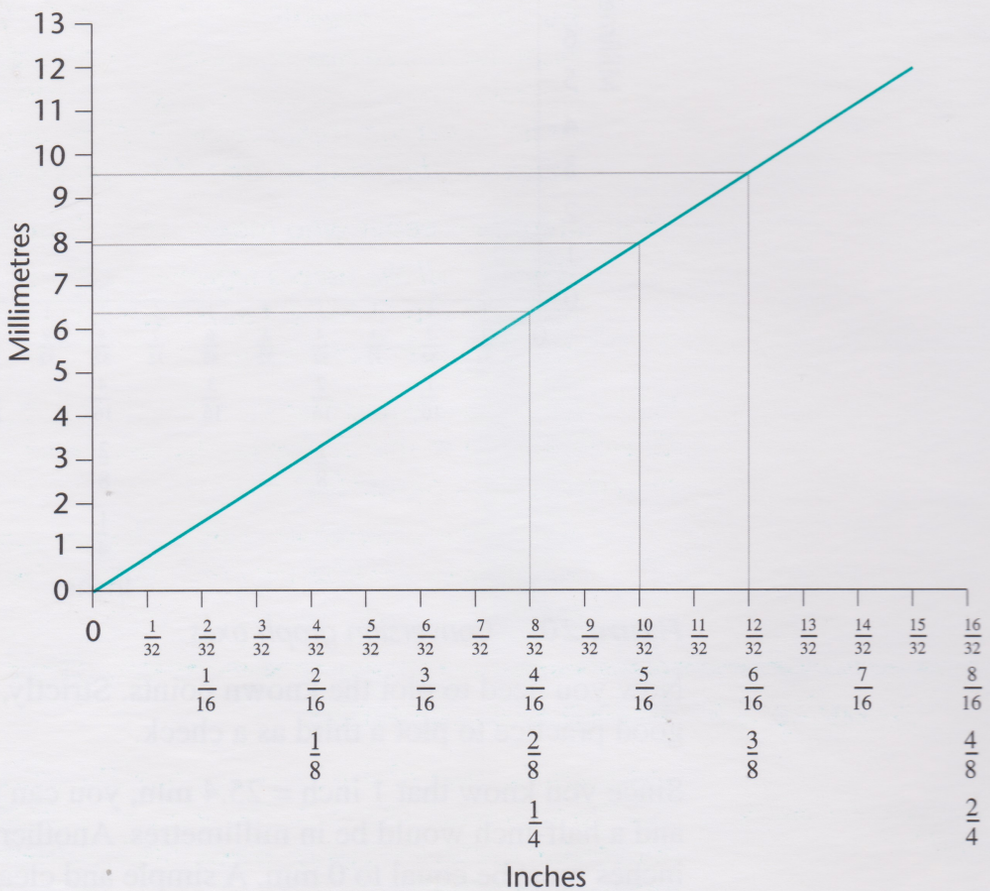


Figure 21 *Conversion graph for inches to millimetres*

The design of hives with movable frames was the beginning of modern beekeeping. At first, beekeepers spaced their frames 'by eye' but this proved to be not accurate enough, and over the years various 'spacers' have been devised, to ensure that the gaps between the frames are within the limits of tolerance. Today, many beekeepers buy the hive boxes ready-made, but make up the frames from kits by nailing pre-cut pieces together.

Activity 54 Framing it

What will the maker of the frame kits have to consider when setting up machinery? What about the person who puts the frames together? Remember, if the spaces between the frames are too small or too big, the bees will fill up the space with propolis or wax and then the frames will no longer be movable.

The maker must ensure that:

Remember from Chapter 3 that tolerances are a way of stating how close a measurement is.

- appropriate tools and careful measuring procedures are used, to ensure that the frames produced will allow beespace between frames to be no less than 6.35 mm and no larger than 9.53 mm
- the assembly of the frames is carried out carefully, with no distortions created.

From a manufacturer of frames:

> *My machinery enables me to have 1/16th of an inch tolerance for each piece overall, which is 1/32 inch each side. I use imperial measurements though I could do it all in metric. The tolerance has to be 1/32 – you've got to get the gap right in order to get the right beespace. If the gap is too wide you get too much wax building up and if it's too small it gets propolized.*

An amateur beekeeper who makes up his frames from kits added:

> *When I nail the pieces together I have to be very careful to get the right-angle correct at the corners – if it's the slightest bit out, the beespace is all wrong.*

Plastic frames are being introduced, but they bring their own problems. One beekeeper in the USA wrote to an Internet newsgroup about his experience with plastic frames.

> *Bees seem to build more burr (brace)comb … than I remember when using wooden frames. Perhaps the 'beespace' is outside the limit?*

Activity 55 More conversions

Say as 'one thirty-second of an inch'.

The manufacturer of the frames quotes the tolerances for his machinery as 1/16 inch and 1/32 inch. These are very small amounts. Use the conversion graph to change them into millimetres and comment on any problems you find.

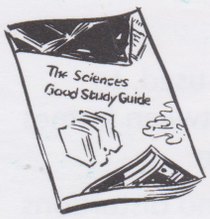
1/16 in = 1.59 mm and 1/32 in = 0.79 mm

To allow for any uncertainties it would seem sensible to quote these to the nearest tenth of a mm: that is, as 1.6 mm and 0.8 mm, to the nearest 0.1 mm.

5.3 Numbers of bees

The number of bees in a colony (one colony lives in one hive) is called the colony population. This number varies according to the time of year.

Figure 22 is a graph drawn from data for a northern, temperate country such as the UK, so you can assume that June is the middle of summer (that is, the greatest daylength). It shows the number of bees in a typical colony at different times of the year.



page 379

Note that the number of days is the independent (known) variable (see page 379 of the SGSG), so time (in days) goes along the horizontal axis, which is also called the x-axis. The number, or the population, of bees is the dependent variable, and so this value is on the vertical axis, also called the y-axis.

The scale is marked in thousands of bees, so 10 denotes 10 thousand. There are four spaces between the zero and the 10 000 mark, so each small space represents 10 000 ÷ 4 = 2500 bees. In fact, most beekeepers 'measure' or count their bees to the nearest 10 000.

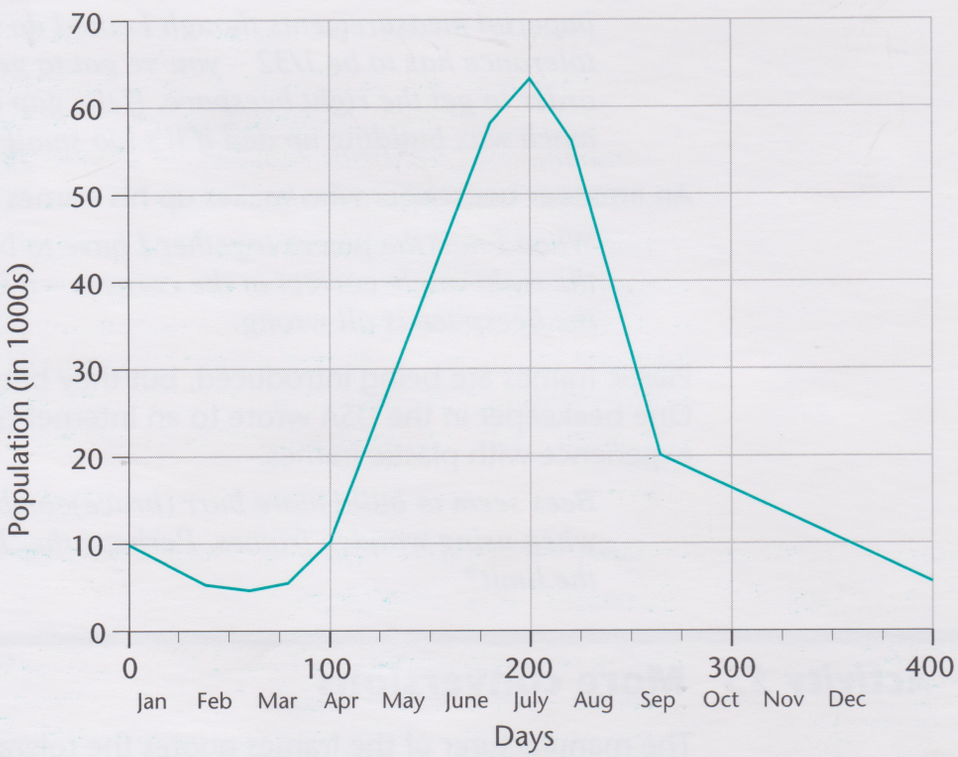


Figure 22 *Graph of bee population at different times of the year (adapted from Hooper, 1991)*

Activity 56 Graph interpretation

page 373 to 375

Work through the part of the Maths Help section of the SGSG on interpreting graphs (pages 373 to 375).

Using the graph above, describe in words the way the population of a bee colony changes through the year. In your description, think about why the population might be varying. You do not need to know all that much about bees to try to work this out!

This activity demonstrates two aspects of science:

- observation of events
- hypothesizing on reasons for events.

Below is a typical description of how the population changes through the year. Between the pieces of information that can be extracted from the graph, a very simplified explanation of the observations is given in brackets.

> *At the beginning of the year there are about 10 000 bees in the hive. [These are old bees and their life expectancy is short. In early spring more bees die than are produced, so …]*
>
> *the number of bees drops until it reaches a low point in March. During March and April, the number of bees is increasing at a fast rate [as the queen increases her rate of laying eggs, and while the quality of the flowers is excellent, providing more food for the bees,]*
>
> *… until it reaches a maximum level of over 60 000 bees in July.*
>
> *[The worker bee is 21 days in the development stage and then lives for a further 30 to 35 days, and so …] by August and September the number of bees drops rapidly and then more slowly until it reaches about 10 000 again at the end of the year.*

If there can be 60 000 bees in one hive, just try to imagine how many bees there will be in the few hives belonging to a small-scale beekeeper, or a commercial bee farmer with several hundred hives. Even try to estimate the numbers of bees in the UK! You will soon reach very large numbers, which are hard to manipulate, and ordinary or scientific calculators may not have enough space on the screen for all the digits.

Scientific notation is useful for both very small and very large numbers.

Activity 57 Scientific notation

page 359 to 364

For the next activity you will need to be able to use scientific notation, so make sure you are confident in its use by working through Section 8 of Maths Help in the SGSG, starting on page 359, before continuing with the text.

Table 17 is an extract from a table giving some statistics for the number of hives (or colonies) in European countries in 1992. As beekeepers do not have to be registered, the figures are only estimates, hence the rounded numbers.

Table 17 Bee statistics

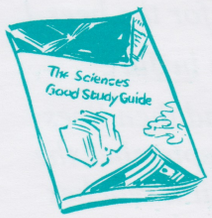
Area	Hives (colonies)		Bee farms		Hives (colonies) per beekeeper	Human population (millions)
	Total	Commercial	Total	Commercial	Commercial	
UK	200 000	40 000	35 000	200	200	56.4
EU	7 540 000	3 160 000	435 000	13 330	237	320

Crawford (1994)

Now you need to use Figure 22 together with Table 17. Hints are given after some of the questions. If you do not want to see the hints, then cover them over with strips of paper.

Activity 58 Practising using scientific notation

Use the graph in Figure 22, and Table 17, to answer the following questions, giving your final answers in *scientific notation.*



pages 147 to 150

(Take care: there is more information in this table than you need, so you will not need to use all of it. Also notice that 200 appears in more than one column: check carefully that you are using the correct value.)

If you are very uncertain how to interpret tables, you'll find Section 5 of Chapter 5 of the SGSG, starting on page 150, very useful: the Hints and Tips are especially helpful.

Take some time to look at the table before you try to answer these questions.

(a) How many commercial bee farms are there in the UK?

(b) How many commercial hives are there in the UK?

(c) How many bees are there in a typical UK colony in June?

For the following questions, write down how you did your calculations so that someone else can follow your working – or indeed yourself in a few weeks' time. At this stage, with the rounded figures, you may not need a calculator.

(d) Calculate the number of bees on a commercial bee farm in the UK in June.

Hint: To work this out you need to know:

(i) the number of hives on a commercial bee farm

(ii) the number of bees per hive, in June.

(e) Calculate the total number of bees on all the commercial bee farms in the UK in June.

Hint: You need to know:

(i) the number of bees on one bee farm in June

(ii) the number of commercial bee farms in the UK.

(f) How does the human population of the UK compare with the bee population on commercial farms in the UK?

For each of the first three questions, you need to extract just one piece of information from the table or graph.

(a) $200 = 2 \times 10^2$

(b) $40\,000 = 4 \times 10^4$

(c) (From the graph) about $50\,000 = 5 \times 10^4$

(d) (i) The number of hives on a commercial bee farm is 200, or 2×10^2

(ii) The number of bees per hive is 5×10^4, the answer to part (c).

So, the number of bees on a commercial bee farm in June is the number of hives on a commercial bee farm multiplied by the number of bees per hive in June.

Therefore, the number of bees on a bee farm:

$= 2 \times 10^2 \times 5 \times 10^4$

$= 10 \times 10^6$

$= 10^7$

(e) (i) The number of bees on one bee farm in June was calculated in the previous question as 10^7

(ii) The number of commercial bee farms in the UK is 2×10^2

So, the total number of bees on commercial farms in the UK is the number of bees on a bee farm in June multiplied by the number of commercial bee farms in the UK.

Therefore, the total number of bees on all UK bee farms

$= 10^7 \times 2 \times 10^2$

$= 2 \times 10^9$

Alternatively ...

The number of bees in one colony in June is 5×10^4.

The number of commercial colonies is 40 000 (which is 4×10^4).

So the total number of bees is the number of bees in one colony multiplied by the number of commercial colonies.

Therefore, the total number of bees on all UK commercial bee farms

$= 5 \times 10^4 \times 4 \times 10^4$

$= 20 \times 10^8$

$= 2 \times 10^9$

(f) The human population of the UK is 56.4 million
$= 56\,400\,000$
$= 5.64 \times 10^7$

The commercial bee population of the UK is 2×10^9.

This means that there are over thirty-five times more commercial bees than people in the UK. But what about non-commercial hives and wild bees?

5.4 Pollen

The last section used scientific notation for dealing with very large numbers: the next section uses it for very small numbers.

Bees collect nectar and pollen to make honey. Beekeepers do not need to measure pollen grains, but they do like to know where the pollen has come from. They do this by checking the colour against a chart. As, Eric Hiam, a beekeeper at Maisemore Apiaries in Gloucestershire, noted:

> *In the evening I look at the colour of the pollen brought back by the bees; different yellows and oranges and sometimes beautiful lime green, and I get out Dorothy Hodges' book to check where the pollen has come from.*
>
> Hodges (1984)

However, botanists (plant biologists) and bee scientists do need to know the sizes of pollen grains. Pollen grains are very small and they are usually measured in micrometres (micro- means a millionth, whereas milli- is a thousandth). A micrometre is also known as a micron and is a metric unit of measure.

You need to be familiar with the SI system and with both ways of writing small numbers: prefixes and scientific notation. These are summarized in Table 18.

Scientific notation is also known as 'standard form'.

Table 18 SI prefixes and standard notation for large and small distances

Prefix	Abbreviation	In terms of a metre	Scientific notation
micro	μm	0.000 001 m	1×10^{-6} m
milli	mm	0.001 m	1×10^{-3} m
	m	1 m	1×10^{0} m
kilo	km	1000 m	1×10^{3} m

Note that μ is pronounced 'mew'.

There are one thousand microns in a millimetre, or, looking at it the other way round, a micron is one thousand times smaller than a millimetre.

Sizes of bacteria are measured in microns: most of them are between 1 and 5 microns in diameter. (If you are interested, you can learn more about the size and shape of bacteria from the box in the Collee article in the SGSG, page 402.)

page 402

Activity 59 Microns to millimetres

Using the information given above, change the following into millimetres.

(a) 500 microns

(b) 200 microns.

(a) 500 microns is the same as 500/1000 mm, which equals half or 0.5 of a millimetre.

(b) 200 microns is equal to 200/1000 mm or 0.2 millimetre.

Figures 23 and 24 show two pollen grains viewed through microscope lenses, with different magnifications.

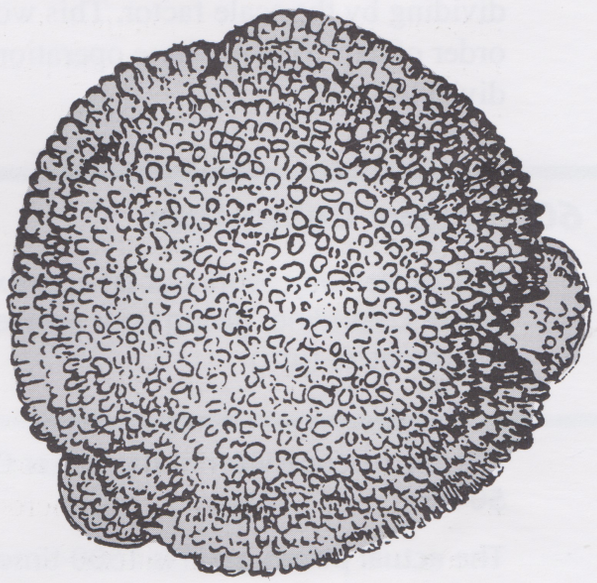


Figure 23 *Blood-Red Cranesbill pollen: magnification ×600 (adapted from Hodges, 1984)*

Figure 24 *Lesser Celandine pollen: magnification ×1500 (adapted from Hodges, 1984)*

You can estimate the size of a pollen grain by measuring its diameter (that is, the greatest distance across the grain, passing through the middle) and then taking the magnification factor into account. Notice that the images in Figure 23 and 24 have different magnifications. As you only need an approximate value to give an idea of the size, you can use rough measurements in this case, which will produce easier numbers to work with.

On the printed image in Figure 23, the diameter of the Blood-Red Cranesbill pollen grain measures about 60 mm. The actual pollen grain is 600 times smaller than this, so you need to divide 60 mm by 600, which gives an answer of one-tenth of a mm (0.1 mm). To express this in microns, multiply it by the conversion factor 1000, which gives:

$0.1 \times 1000 = 100$ microns or 100 μm

You could equally, of course, change the millimetres to microns first, before dividing by the scale factor. This would produce the same answer, as the order of carrying out these operations does not matter for multiplication or division.

Activity 60 Lesser Celandine

In a similar way, work out an approximate size for the pollen grain of the Lesser Celandine, giving your answers in both millimetres (mm) and micrometres (μm).

The microscope view of the Lesser Celandine pollen grain measures about 50 mm.

The actual pollen grain is 1500 times smaller than this, so the actual size is about:

$50 \text{ mm} \div 1500 = \frac{1}{30}$ mm or 0.033 mm

Converting this to microns:

$0.033 \text{ mm} \times 1000 = 33$ μm

Using micron measures to compare the sizes of the two types of pollen grain gives a better sense of the difference in size. The cranesbill pollen grain is actually three times larger than that of the celandine.

Activity 61 Thinking about notation

page 405

In this chapter, and throughout the module, you have experienced different ways of writing numbers: fractions, decimals, percentages and scientific notation.

Reflect on the occasions when each of the different alternatives is used, and the advantages and disadvantages of each.

This is the time to ensure that you are totally confident about using all of these ways of writing numbers and converting between them. Use the SGSG index to find practice examples, and if you are still not very confident, work through them.

5.5 Summary

This chapter has considered three measurement topics in relation to beekeeping:

- beespace (technology)
- bee populations (mathematics: statistics)
- pollen size (science: botany).

These topics have been used to give you a 'feel' for handling numbers and notation for very large and very small measurements. However, no explicit reference has been made to the measurement issues considered in previous chapters.

Remember to keep your Study Folder organized and up to date.

Activity 62 Measurement issues

For each of the topics in this chapter, write down an example, aspect or question which relates to the major measurement issues of:

(a) purpose
(b) boundaries
(c) units
(d) methods, tools and use.

Learning Outcomes

You should now understand that:

- measurements need to be fit for a specific purpose
- scientific notation helps in understanding measurements of different magnitude
- knowing when and how to do calculations is only the first step: practice leads to fluency and greater understanding
- different mathematical notation makes calculating easier in different contexts.

You should now be more able to:

- draw and use a conversion graph
- interpret line graphs
- use scientific notation and SI units
- read off and calculate from information in tabular form
- scale measurements up or down, using enlargement factors.

CHAPTER 6 CONCLUSIONS

What we call the beginning is often the end,
And to make an end is to make a beginning.
The end is where we start from.

T. S. Eliot (1969) *Four Quartets*, 'Little Gidding' V

6.1 Introduction

This module has introduced a range of measurements, units, measuring tools and procedures used in a number of contexts. Some will have been familiar, and others new to you. You have also used different learning media, such as text, diagrams, graphs, charts, maps, an audio-cassette and practical measurements. These experiences were designed to help you not only to become more familiar with and adept in using measurements, but also to learn how you can best study effectively.

This final chapter puts into context the module's themes about measurement and about the whole process of studying. It therefore includes some consideration of measurement as part of the disciplines of mathematics, science and technology. It is, however, principally concerned with your studies and how you can:

- reflect on your learning
- develop strategies to help you retain and use the knowledge and understanding gained
- plan the next step in your studies.

6.2 Conventions

As was said at the beginning of the module, the disciplines of mathematics, science and technology are concerned with:

- quantifying objects, energies, populations, materials and spaces
- dimensional relationships.

They are also concerned with comparisons and with communicating results across the world. As has been emphasized in this module, there is now international agreement on the use of SI units. Within the various sciences, however, there are subtle differences in how measurements and units are used. These variations arise from the conventions used in particular disciplines and reflect the purposes for which the measurements are intended.

Activity 63 Woolly thinking

Listen to the last section of the audio-cassette. It is intended to be fairly light-hearted but it should also give you food for thought.

Measurement is an important activity across the experimental and observational sciences. The field contains many different disciplines, which use measurement for comparing almost everything in the world. Technology, too, is concerned with measurements, both in the design and manufacturing stages and in various aspects of engineering, such as acoustics and mechanical, electrical and civil engineering.

I hope that listening to the various comments will encourage you to find out more about the MST disciplines and to take your studies further.

6.3 Issues in measurement

As you progress in your study of mathematics, science or technology, you will meet other measures, tools and methods, but the issues involved will be similar to those you have met in this module.

Activity 64 Putting it all together

pages 228 to 256

Skim through the section on writing in Chapter 9 of the SGSG (beginning on page 228). Scan for the Key Points and read them carefully. Pay particular attention to Section 5.4, page 256, on essay writing.

Write an essay on the important issues in measurement.

To help you, the stages of writing such an essay are outlined below.

1 Look through the summary notes you have made for each chapter. What are the main issues that might apply to any measurement or measuring task?

2 List them, and then write a paragraph or two about each one, including an example, preferably one from your own experience. If you can't think of any, you could use one of those included in the module.

3 Assume that the audience you are writing for is someone like yourself who has not studied this module. You may find it easier to explain some of the ideas by using diagrams, either your own or diagrams adapted from those in the module. Ensure that you use your own words, but if you do copy anything directly from this text or any other source, make sure you indicate this clearly, by using quotation marks, for example.

4 Read through the paragraphs you have written, and decide on a logical order for presenting them to someone who knows very little about measurement.

5 Finally, draft two further paragraphs:
   - an introductory one, to set the scene
   - a concluding one, giving the essence of the other paragraphs.

You have now produced a draft essay! The next stage is to turn this into a polished piece of writing.

Check that:

- it covers all the points needed, but not in excessive detail
- it is easy to read and has a logical flow
- any diagrams are labelled and have a title.

Make any changes necessary to produce the next version. Now give it a title, and add at the end a list of the sources of your information, particularly the sources of any quotations used.

The purposes of writing this essay were both:

- to help you to summarize what you have learned
- to give you some experience of trying to communicate this learning to someone else.

To see how successful you are at communicating to someone else, give the essay to a member of your family or a friend to read and ask for comments.

pages 228 to 269

Essay writing takes time to develop. It is another case in which you should not expect total learning straight away! Make a note in your Study Diary to read Chapter 9 of the SGSG, which talks about the 'art' of scientific writing. For the moment, you might find it useful to skim through the chapter's Key Points again.

The important thing is that you now know and understand rather more than you did at the beginning of the module.

In this exercise you may have found some areas difficult to explain because your own understanding was not quite good enough. Full understanding frequently emerges only over time.

6.4 Retaining knowledge and understanding

Throughout this module you have been asked to undertake activities, write notes, and summarize your learning. All these will have helped to 'fix' the knowledge and ideas into your long-term memory. However, unless the knowledge is regularly 'exercised' it may gradually fade. It is one thing to get fit, quite another to remain fit. The same applies to study skills: they must be practised. This does not necessarily mean you have to keep studying, but rather that you should use the awareness and skills in other contexts.

For example, you are probably more aware of units of measurement and how they are written than you were when you opened the module, so continue to notice when and how measurements are quoted on television, in the papers or in everyday life. Think about how the measurements were made and how exact they might be. Talk to other people about what you have learned.

6.5 Thinking about studying

In studying this module you will have gained and practised a variety of study skills.

Activity 65 Reflection

Reflect on the study skills you have acquired or improved. What have you learned about your own strengths and weaknesses? In which areas do you need to gain more experience?

To help you answer these questions, look through your Study Folder and then complete an audit of your study skills.

One way of doing this is by using the checklist given in Table 19. Decide for yourself how you are to rate your skill levels (poor, adequate or good, for example).

If you rate your skill levels before and after doing the module (by using a different mark or colour), you will be able to take some satisfaction in your progress.

Then decide on your priorities for further study. For example, 1 for a high priority (next week?), 2 for important (next month?) and 3 for a low priority (only when time allows).

Table 19 Personal skills audit

Skill	Skill level 1	2	3	How do I know? What evidence can I provide?	Priority 1	2	3	SGSG references
developing strategies for effective study and use of time								Chapter 1
rapid reading techniques, such as skimming and scanning								Chapter 2
extracting ideas and information from audio presentations								Chapter 2
writing notes and summarizing key points								Chapter 2
performing basic calculations and presenting the results								Chapter 4 Maths Help
measuring and tabulating data								Chapter 5
processing data to obtain the range, mean, median and mode								
interpreting graphs and charts and obtaining information from them								Chapter 5
an appreciation of the idea of uncertainty in measurement								
explaining and using scientific and technical terms								
understanding and using scientific notation in numerical work								Chapter 5
acquiring tactics for getting help when stuck								Chapter 2 Chapter 4

Activity 66 To finish the module

Look through the work you have produced for this module and check that it is all organized in such a way that you would be able to refer back to it at a later date. You might, for example, need to produce your Study Folder as proof of previous study, so your Study Diary section is worth keeping, as well as notes on the text and the activities.

6.6 What next?

Now that you have finished this module you have to decide what to do next. From Activity 65 you may already have decided that you need to do more work on study skills, perhaps by working through some of the chapters of SGSG, or by doing another module in this series.

Good luck in all your future studies.

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Text

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Figures

Figures 23 and 24: adapted from Hodges, D. (1984) *Pollen Loads of the Honey Bee*, International Bee Research Association.

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THINKING ABOUT MEASUREMENT

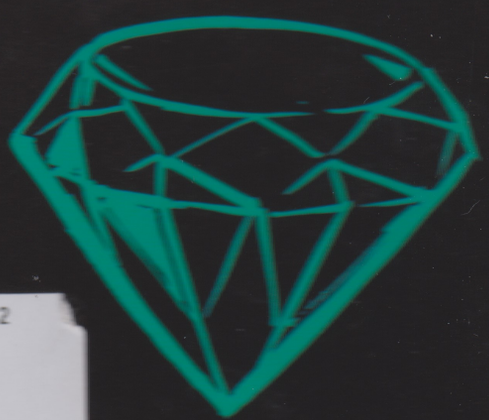
Have you ever wondered ...

- How to convert from miles to kilometres?
- How to adapt a recipe to feed a hundred people?
- How to find the average of several measurements?
- What scientific notation is, and how to use it?

Whatever your background, if you want to understand why we make measurements, what we measure, and how, this is the study module for you.

Thinking about Measurement is part of *Breakthrough to Mathematics, Science and Technology* , a series of study modules that introduces some of the key ideas and skills involved in studying mathematics, science, technology and engineering. This module has a mathematical flavour, and includes the interpretation of graphs, basic calculations and the use of tables. It uses a variety of everyday examples to illustrate how mathematicians see the world.

The set book for this series, which must be purchased separately, is *The Sciences Good Study Guide* by Andrew Northedge, Jeff Thomas, Andrew Lane and Alice Peasgood. It is published by The Open University.



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